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Space Administration

SPACE STATION DEVELOPMENT PLAN

Submitted to the

Committee on Science, Space and Technology
U.S. House of Representatives

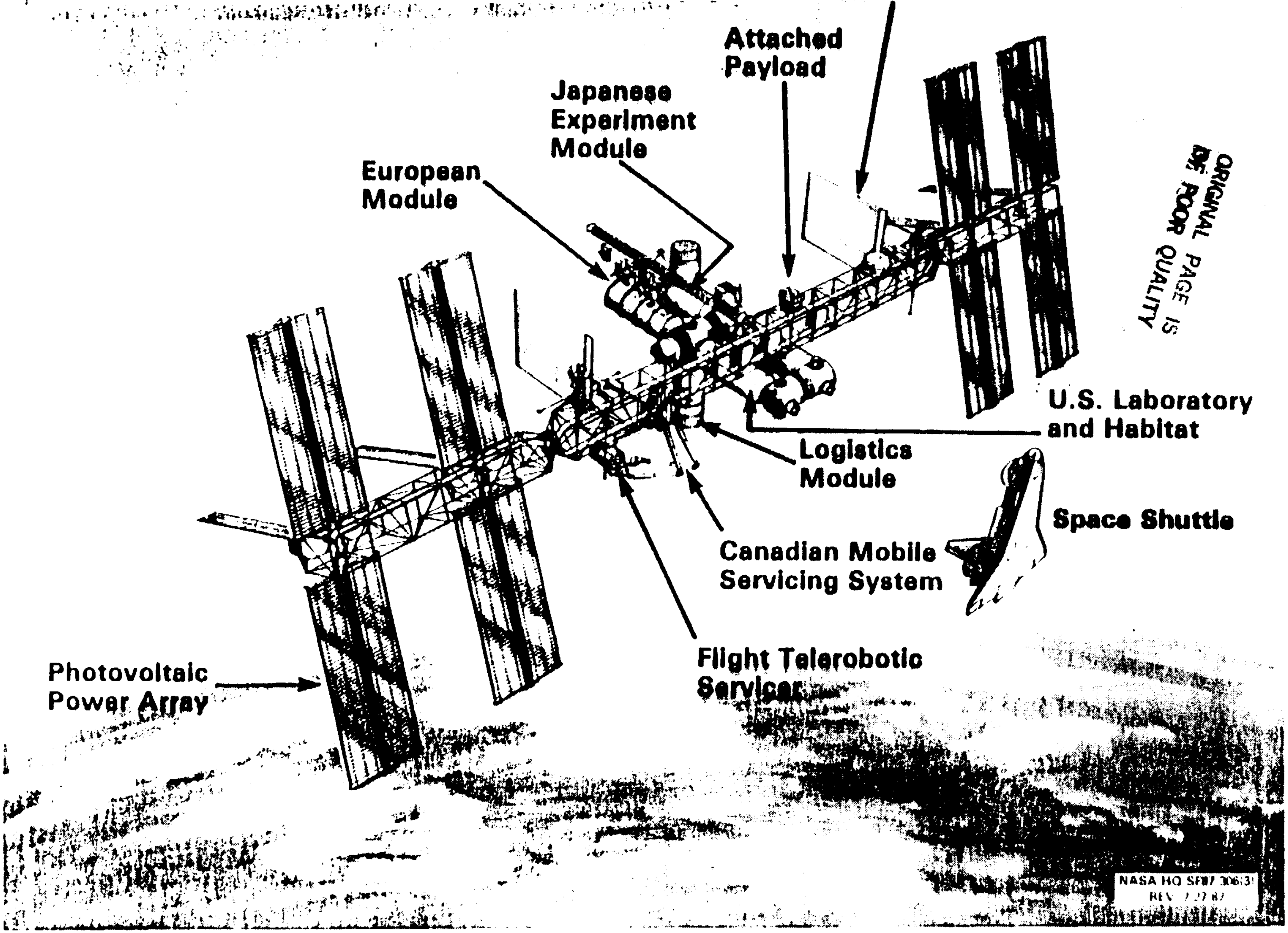
NOVEMBER 1987

PREFACE

The Space Station Development Plan is submitted in response to a request by the Committee on Science and Technology, U.S. House of Representatives, in Report No. 99-829. This report, dated September 16, 1986, dealt with FY 1987 NASA authorization (H.R. 5495). The Space Station Development Plan is submitted in conjunction with reports on Science Operations Management and Operations Cost Management.

This plan is based on Space Station Program internal planning and control documents. Those reference documents specify approved Program requirements and schedules and are under configuration control. This plan, at the time of publication, is consistent with those documents and represents Program planning as of the completion of the definition phase but prior to initiation of development activities. It is consistent in content, schedule, and cost with the program which was endorsed by the Administration in April 1987. During the implementation of Space Station development changes which occur in the Program baseline will be reflected in annual updates to this Plan.

Space Station Manned Base



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SPACE STATION DEVELOPMENT PLAN

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INTRODUCTION

A Laboratory in Space

The United States is building a new national laboratory – the Space Station. As a research facility in space, it will provide opportunities for significant advances in science, technology and commerce. Orbiting the Earth once every 90 minutes, the Station will take advantage of the unique Space environment. The near absence of gravity (microgravity) will enable the U.S. to conduct productive research in life and materials sciences and to conduct scientific observations of the Earth and the stars.

The Space Station, unlike any spacecraft yet developed by the United States, will be permanently manned. Time on orbit will no longer be constrained to a few days. No longer will we visit space, men and women will be living and working in space continuously. Machines, however sophisticated, cannot do what the Space Station crew will do: think and react to the unexpected. Human presence is the key to providing a Station that has creative and dextrous capabilities.

A Stepping Stone in Space

In the future, Americans will again venture beyond the environs of Earth. The objective of the Apollo Program, to explore the moon, was a beginning not an end. Expeditions to Earth's sister planet Mars, or back to the moon, will inevitably take place. When this will occur and who will do it are uncertain as other nations throughout the next century expand their technical capabilities to meet these goals.

Any such missions would utilize a Space Station as a point of departure. But much preparatory work is required if these missions are to be considered in the future. Technologies must be developed, experience in complex space operations must be gained, and knowledge of the effects of extended space flight on humans must be expanded. A Space Station provides the essential facility in which to carry out these tasks. The Space Station represents an investment in these activities but would not be a commitment to a manned mission to Mars or a return to the moon. Such future missions would better be accomplished by first developing the Space Station. It will be our stepping stone in space, if we choose to make it so.

The Space Station Program

This development plan describes the Program that NASA has established to build the Space Station. The Program draws upon the experience of both NASA and industry. It is shaped by the availability of resources, the elements of schedule and the capabilities desired. It is shaped also by NASA's insistence on developing a Space Station that is truly first-rate in capability. The Station must be a research facility capable of supporting a variety of scientific disciplines. It must be flexible yet durable in its capabilities, as the Station will be on orbit for many years. It must be operationally affordable for its success will be measured by its operational use and not its development.

Space Station must be compatible with the Space Shuttle, which will reflect the intention of the United States to remain the leading nation in space as the 20th Century comes to a close.

Program Planning

The Space Station program differs from previous NASA endeavors in a number of significant ways. Program planning has been based on an extended period of detailed definition by NASA with parallel efforts in Canada, Europe, and Japan. The modular Station design, consistent with current launch capabilities, dictates multiple launches and on-orbit assembly. U.S. development and test responsibilities are distributed among five NASA centers to draw on unique skills and resources throughout the agency. The efforts of these centers and their aerospace industry contractors will be integrated by the NASA Headquarters Space Station Program Office (SSPO) in Reston, VA. The SSPO will be assisted by the Program Support Contractor (PSC). The SSPO will also have the responsibility for integrating major international elements into the Program.

The Program differs also in the potential for having private sector participation in space station development and operations. NASA policy welcomes private funding of dedicated Space Station systems and services.

The participation in Space Station development by many NASA programs is another unique aspect of this program. The Space Station will provide a key part of the overall capabilities needed to accomplish civil space objectives. In addition to the participation of the international partners, the NASA Office of Space Flight, Office of Space Operations, Office of Space Science and Applications, Office of Aeronautics and Space Technology, Office of Commercial Programs are providing support to the Office of Space Station that is essential to a successful Program. Cooperative agreements and compatible plans for Station development and operations are key elements of the development strategy.

An unusual but significant aspect of the Space Station is its long operational life. This space-based facility is designed to be permanently inhabited well into the next century. Manned and unmanned elements must be designed to permit changes to avoid obsolescence and to accept efficient on-orbit maintenance and resupply.

Operations capability is an element of Space Station planning. The development of this capability is consistent with hardware and software systems development in all respects: schedule, cost, budget, management, and design compatibility. Operations studies leading to design requirements are being conducted as an integrated part of the development. Engineering and operations schedules are coordinated to ensure the operations facilities are in place and the manpower is trained to meet the hardware processing, launch, and assembly schedules. An operations task force developed a management concept and recommendations for system design and operations which are now being implemented in the Program. The recommendations on how the Program should support users and how user groups might be organized have been studied and reported on by a Science Operations Working Group. Design compatibility will be ensured through operations suitability and supportability assessments. These assessments will review designs and plans to verify that they meet operations requirements and can be supported with available resources. An Operations Cost Management Plan will allow trade-offs between development and operations costs to obtain low life-cycle costs.

At the request of the Administration, the National Research Council (NRC) conducted an independent review of the Space Station Program which considered Program objectives and requirements, potential phasing of capabilities, costs and lower cost alternatives, and Station capabilities and Program schedules. The review was completed in September and the NRC made a number of recommendations. NASA agrees with most of these recommendations and is particularly encouraged by the NRC's endorsement of the Space Station configuration.

Space Station cost estimates have been developed and extensively reviewed. An intensive 21-month Phase B definition produced reliable cost estimates that were reviewed for over a year by NASA, the Administration, and the NRC. The result is a development program that has remarkably well-understood cost parameters. As reported earlier to the Committee on Science, Space, and Technology, the cost estimate for Space Station is $14.6 billion in 1988 dollars.

The Development Plan

This development plan presents the strategy and structure of the Space Station Program Office. It contains a top-level Program description. The Plan begins with a review of Space Station Program Objectives and Requirements.

I. REQUIREMENTS

A. PROGRAM OBJECTIVES AND REQUIREMENTS

Program Objectives

In 1981 NASA Administrator James Beggs stated the widely held belief that the next logical step for the U.S. space program was to build a permanently manned space station. The Space Shuttle had flown, and the establishment of a permanent facility in space to which the orbiters would shuttle was a step the United States would have to take were it to continue to lead in the exploration of space. On January 25, 1984, following several years of requirements studies, in depth reviews, and Presidential briefings, President Reagan issued a mandate in his annual State of the Union address to the nation: "We can follow our dreams to distant stars, living and working in space for peaceful, economic, and scientific gain. Tonight, I am directing NASA to develop a permanently manned space station and to do it within a decade."

The Space Station will add new momentum to the civil space program and is essential to realizing the national goal of restoring U.S. leadership in space. The objectives of the Program are:

(1) To establish a permanently manned research facility in low-Earth orbit by the mid-1990s with the capability to evolve to meet future needs;

(2) To enhance and evolve mankind's ability to live and work safely in space;

(3) To stimulate technologies of national importance (especially automation and robotics) by using them to provide Space Station Program capabilities;

(4) To provide cost-effective operation and utilization of continually improving facilities for scientific, technological, and operational activities enabled or enhanced by the presence of man in space;

(5) To promote substantial international cooperative participation in space;

(6) To create and expand opportunities for private-sector activity in space;

(7) To provide for the evolution of the Space Station Program to meet future needs and challenges; and

(8) To provide unmanned platforms for long duration scientific and operational observations.

The combination of manned, unmanned, and automated systems will establish a broad spectrum of capabilities responsive to both currently identified and evolutionary needs of space science, technology, and commerce.

Program Requirements

The Space Station Program will include a permanently manned Space Station, unmanned platforms, and the associated ground-based infrastructure. The major physical elements of the configuration provided by the United States will include pressurized habitation and laboratory modules with a shirt-sleeve environment for crew habitation and for conducting experiments under microgravity conditions, resource nodes for command and control, airlocks for Extravehicular Activity (EVA), accommodations for attached payloads, the Flight Telerobotic Servicer (FTS), a polar orbiting platform, logistics elements, and EVA capability.

The configuration is expected to include elements provided by the Program's international partners. These elements are the Japanese Experiment Module (JEM) which includes a pressurized laboratory, an exposed facility for payloads, and a logistics module; the Canadian Mobile Servicing System (MSS); and the European Space Agency (ESA) pressurized laboratory, polar orbiting platform, and Man-Tended Free Flyer (MTFF).

The Space Station will be able to support a crew of eight and provide a total average power level of not less than 75 kW using photovoltaic arrays.

The ground-based infrastructure needed for Space Station operational capability will include facilities for mission control, logistics support, launch processing, training, testing, and user operations.

The on-orbit capability will increase during the assembly sequence leading to complete deployment and operation of the station. Growth of on-orbit capability will have the following characteristics:

(1) The FTS will be available early in the Program so as to support assembly and maintenance tasks and payload installation.

(2) Attached payloads will be added before the manned modules are launched.

(3) Man-Tended Capability (MTC) will be achieved with the addition of the laboratory module. MTC will provide for support of selected payloads and experiments prior to the time at which a crew is continuously present.

(4) The flight sequence will include the launch of both U.S. and ESA polar platforms (each with integrated payloads) into high-inclination polar orbits to provide capability for scientific and operational Earth observations.

(5) Permanently Manned Capability (PMC) will be achieved with the inclusion of the U.S. habitation module, safe haven provisions, and Space Station-based EVA capability. At this point the Space Station will be capable of continuously supporting a crew of up to eight people.

Space Station elements will be delivered to orbit by the National Space Transportation System (NSTS), except for ESA delivery to orbit of the ESA polar platform and MTFF. Alternative transportation modes that could increase Program margins and reduce requirements placed on the NSTS are under study. Five shuttle flights per year for sustained operations will be the Program baseline. The Space Station Program will require launch support from both the Eastern Test Range and Western Test Range.

Evolution is the process of increasing the on-orbit capability of the Space Station to meet evolving requirements. The Space Station design will facilitate future evolution by including provisions for adding payloads, increasing resources such as power, new functional capabilities such as accommodations for an Orbital Maneuvering Vehicle (OMV) or a servicing facility, a co-orbiting platform, and the incorporation of new technologies.

Top-level Program requirements are specified in the Program Requirements Document (PRD). The design requirements for Space Station development are specified in the Program Definition and Requirements Document (PDRD). The hierarchy of program documentation is shown in Figure I-1. Element and system performance capabilities are described in Appendix A, System Description.

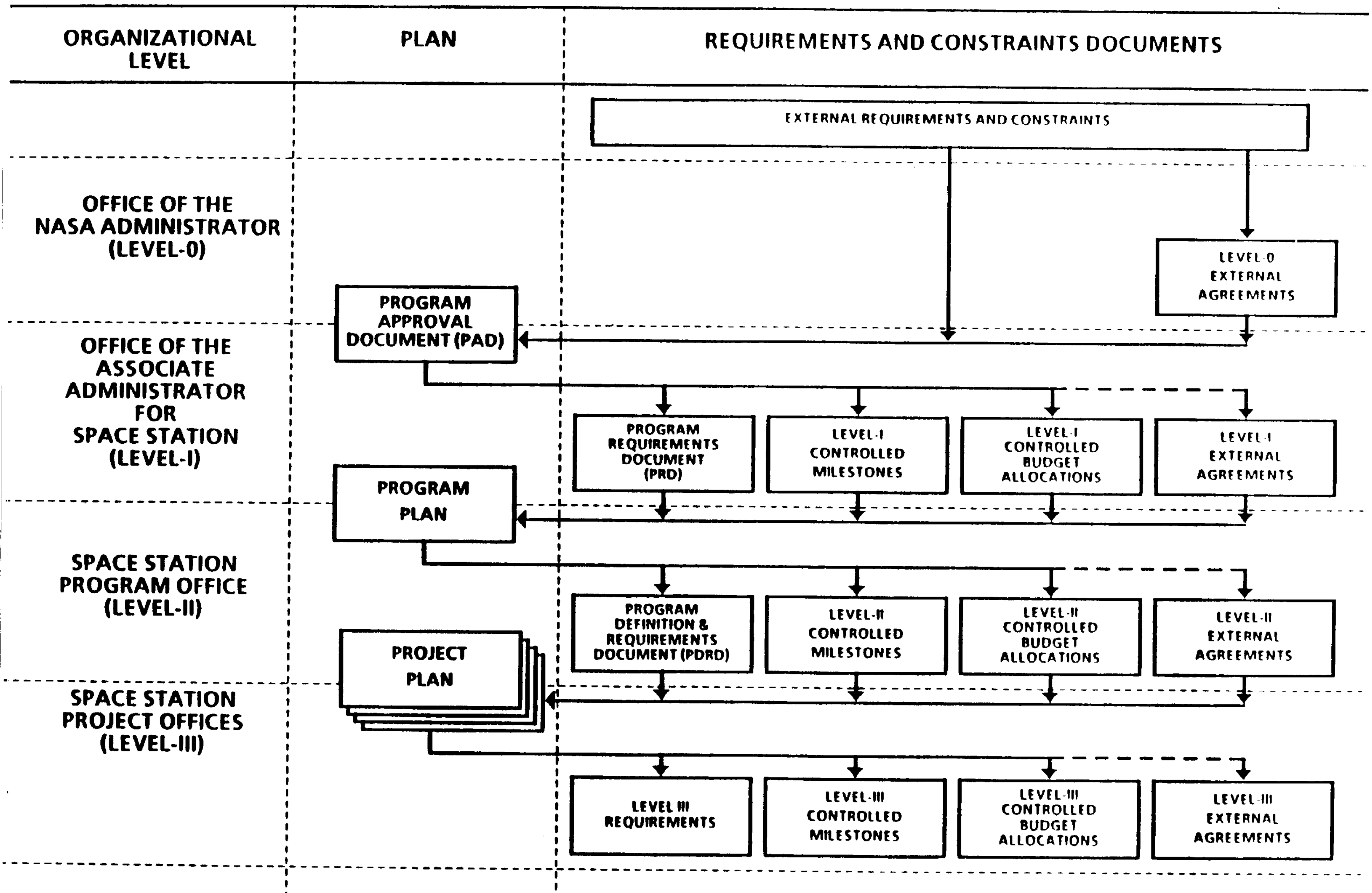

FIGURE I-1. SPACE STATION PROGRAM DOCUMENTATION FRAMEWORK

B. UTILIZATION

User Requirements

Utilization of the Space Station has been the focus of Program conceptual and definition studies. Two years before the start of Phase B definition studies, prospective users were asked to propose potential payloads for the Space Station. Workshops were held to review these prospective payloads. These payload descriptions were compiled into a Mission Requirements Data Base (MRDB) containing over 300 individual potential missions or payloads.

The MRDB is a computerized data base that can support a variety of Space Station design accommodation studies. The MRDB will be updated throughout the life of the Space Station to assess the adequacy of payload accommodations and to evaluate the need for evolution of Space Station accommodations. An analysis of the early MRDB provided the basis for the initial set of user requirements placed on the Program.

Payloads for the initial phase of the Space Station have been recently identified by the Office of Space Science and Applications, Office of Aeronautics and Space Technology, and Office of Commercial Programs. These candidate payloads will be maintained as a near-term mission subset. Additional subsets containing candidate payloads to be accommodated in later Program phases will also be developed. The subsets will be used to conduct detailed accommodations studies for the early phase of the Space Station development program.

User Accommodations

Space Station user accommodations were initially identified and integrated into Space Station systems and configurations designs based on extensive analyses of the MRDB. These assessments were aided by extensive interaction with users and user sponsors in the Space Station User Requirements Working Group, International Utilization Coordination Working Group, the Task Force on Scientific Uses of the Space Station, the Commercial Advocacy Group, the Technology Advocacy Group, the Space Station Mission Integration Panel, and other user working groups and technical systems panels.

To confirm the adequacy of user accommodations and to assess the Program's ability to support new payload requirements will require detailed accommodations studies during the development phase. The studies will assess candidate sets of payloads and develop potential manifests. These activities will include both U.S. and international payloads. Payload viewing and pointing angles, power availability, data and command system capability, disturbance environment, optimum locations for payloads sensitive to contamination and electromagnetic fields, crew operations support, remote manipulator support, and resupply logistics are some of the accommodations that must be addressed.

Extensive accommodation analyses have been conducted for payloads in microgravity materials and life sciences, Earth observations, technology, astrophysics, plasma physics, induced environment, and planetary studies. Pointing payloads such as the Tropical Rainfall Measurement Mission and the Solar-Terrestrial Observatory solar observing instruments have played an important role in determining the level of Space Station support required for payload pointing.

Materials-processing equipment such as crystal growth facilities (e.g., for protein and gallium arsenide crystals), a containerless materials processing facility, and fluids processing facility (e. g., for electrophoresis) have been drivers in determining the microgravity requirements for the Space Station and in turn the location of the modules with respect to the truss. Life science payloads, biomedical and biological, also have microgravity requirements.

Crew intensive experiments are primarily those inside the laboratory in particular the life science biomedical and biological payloads. Depending on the degree of automation, some materials-processing experiments will also require substantial crew support. The majority of the external payloads are automated or can be operated extensively from the ground. Exceptions are instruments or payloads which require extensive crew interaction to provide the desired data.

Accommodation studies of space assembled payloads such as the Large Deployable Reflector, geosynchronously deployed antennas, and assembly support manned lunar and Mars missions are ongoing. Additional facilities such as a large positioning mechanism or crane may eventually be needed to support assembly activities in a future growth phase after the current program.

In addition to these primary accommodation assessment activities, developments in A&R will be emphasized to ensure that the Space Station takes advantage of capabilities which can greatly increase payload productivity and utilization with minimal cost increases.

The Task Force on Scientific Uses of Space Station of the NASA Advisory Council served to bridge the NASA scientific user community and the Space Station. NASA has begun to establish a follow-on group to continue this service. Selection of a chairman and members is under way.

The NASA Headquarters organizations representing the science, technology, and commercial users have recently submitted an updated assessment of the payloads supported by the user community for manifesting during the assembly of the Space Station. These payloads are typical of what can be expected for the Space Station.

For example, before the Man-Tended Capability (MTC) is achieved, the baseline assembly sequence will provide the capability to install payloads on the transverse boom which would provide the following: (1) measure and assess the Space Station plasma environment to improve our understanding of the physical interactions between large structures and space plasmas and to gain a better understanding of the physics of space plasmas (e.g., Space Station Plasma/ Environment Monitoring System); (2) collect meteoroid and cometary dust for analyses related to solar system evolution, planetary formation, and the development of life in a planetary system (e.g., Cosmic Dust Collection Experiment); (3) study solar phenomena (near the peak of the solar cycle) and the interaction of the solar wind and Earth atmospheric and magnetospheric processes (e.g., Solar-Terrestrial Observatory solar instruments); (4) evaluate the effectiveness of using laser beams as data communication links between satellites and spacecraft (e.g., Laser Communications Engineering Test); and (5) study the effectiveness of different types of materials and coatings in resisting oxygen erosion, solar ultra-violet degradation, and orbital debris effects (e.g., Spacecraft Materials and Coatings). Some sensors such as accelerometers, strain gauges, and contamination and plasma monitors may be integrated into the truss structure as it is assembled to characterize the Station.

Subsequent flights will deliver the U.S. laboratory and additional payloads and payload support equipment for the laboratory and a node. Payloads similar to the following will be included: Commercial Protein Crystal Growth Facility, Isoelectric Focusing Experiment, Two-

Phase Fluid Behavior and Management Experiment, Biomedical Research Project Experiment (may be located in Node 4), Very High Speed Integrated Circuit Fault Tolerant Processor, and Manned Observations Techniques. Other payloads such as Quantized Vortex Structure, Transient Upset Phenomena in Very Large Scale Integrated Circuits, Modular Containerless Processing, Organic Crystal System, and Life Science Biomedical and Biological Research Project payloads will be delivered by later flights.

The Utilization and Operations Board (UOB), a part of the Space Station Control Board structure, will be the primary means to obtain approval for user accommodation changes, additions, and reductions. The UOB will sponsor several important working groups including the Pressurized Payload Accommodations Working Group and the External Payloads Accommodations Working Group. These and other working groups will address user accommodation concerns, review proposed design changes, and preview and status the results of major Program design review activities. Section IIB describes the structure of Program boards and panels.

C. OPERATIONS INTEGRATION

As noted in the introduction, the Space Station Program draws heavily upon the resources and capabilities of other NASA Offices for its support. The Office of Space Flight is necessarily relied upon to provide the NSTS for transportation and to support on-orbit assembly and integrated operations. It is the intent of the Space Station Program to develop a manned base and a series of platforms that satisfy user requirements within the integrated support capabilities of the NSTS, TDRS, OMV, and Space Station Programs. To this end joint working groups and agreements will be established to coordinate and assess the needs of the Space Station Program. The goal of these working groups will be to blend the new Space Station capabilities with the existing capabilities and capacities of the manned programs.

The integrated approach will also benefit user integration by utilizing the complete on-orbit support provided by the combined capabilities of the Office of Space Flight, Office of Space Operations, and Office of Space Science. The various Space Station management boards will include membership from the other NASA offices to ensure compatible and integrated concepts and implementation through their participation in the decision making process.

The Space Station Program is responsible for developing a Space Station that can be implemented, assembled, and operated with the coordinated capabilities of all manned Program elements. Manned base assembly operations will be a joint OSF and OSS activity with OSF performing the on-orbit assembly tasks. OSS will provide compatible flight hardware and support operations to this activity.

The Space Station Program must also blend easily with the unmanned programs of NASA, specifically the Space Science program and the data tracking activities. OSO and OSSA will provide essential operations support.

D. INTERNATIONAL PARTICIPATION

President Reagan's 1984 State of the Union message included a call to friends and allies of the United States to participate in the Space Station Program. He stated, "NASA will invite other countries to participate so we can strengthen peace, build prosperity and expand freedom for all who share our goals."

Even prior to this call, NASA planning criteria included the potential for significant international participation in the Program. It was understood that such participation, in addition to continuing the NASA tradition of international cooperation in space activities, had significant potential for enhancing Space Station capabilities, supporting U.S. foreign policy objectives, and sharing the risks and operational costs of the endeavor. Through cooperation enhanced overall capability can be achieved with minimal shared investment in development and operation.

In 1982, NASA initiated studies of Space Station needs, attributes, and architectural options. In addition, potential partners in Europe, Canada, and Japan conducted parallel studies. All potential partners responded enthusiastically, and the results of the parallel studies were shared in the spring of 1983 and factored into preparations for the definition phase. The potential partners also participated in a concept development group formed by NASA in 1983. They studied selected tasks and the results were shared in workshops. In order to further coordinate predefinition activities and share status information, international meetings were held in Washington, D.C., in 1984 at which preliminary guidelines for international cooperation were presented by NASA and discussed with officials from Canada, ESA, and Japan.

Agreements to set the framework for cooperation in the definition phase were signed in the Spring of 1985 with Canada, ESA, and Japan. These agreements included preliminary design and definition studies and established a process to identify elements of the Space Station that could be developed by the partners. Based on the process established by the Phase B agreements and preliminary results of the definition studies, Program level agreements were reached in 1986 with all three partners. These agreements identified hardware elements which each partner would study for development, subject to further agreements on the detailed design, development, and operations and utilization phases. These agreements will provide bilateral management mechanisms for the development phase set forth in Section IIB, Management Approach. The international hardware elements are described in Appendix A, System Description.

The approach for international cooperation in the Space Station Program is based upon successful practices followed by NASA in more than 25 years of cooperative international activities. Because of the maturity of foreign aerospace capabilities and because any Space Station cooperation would extend for a considerable length of time, NASA has understood that any such cooperation would be on the basis of partnership. While NASA retains overall Program direction, the international participants will have a major role in Station development and operations. The long term nature of the Space Station Program dictates additional considerations; therefore, the partners are developing long term utilization plans and will be responsible for selecting and prioritizing their own users. They will remain responsible for the elements they provide and will maintain and support the ongoing operations of their respective elements. Special care will be taken to ensure that no unwarranted transfer of U.S. technology occurs. International partners will provide personnel to serve as crewmembers and will share the operations costs of the Space Station. Multilateral management mechanisms will be established to determine strategic and resource allocations. Details of the international roles and responsibilities are the subject of current negotiations. Other aspects of international participation are described in relevant sections as appropriate.

Currently studies are being conducted to determine the feasibility and salient features of international partners (ESA and Japan) providing their logistics transportation via their launch vehicles.

II. IMPLEMENTATION

A. DEVELOPMENT STRATEGY

Introduction

The purpose of the Space Station Program is to provide space-flight users with operational capability consisting of Earth-orbiting manned and unmanned facilities and the requisite ground operation and support systems.

The Space Station configuration described in this document will provide the United States and its potential international partners with a facility capable of supporting a permanent, manned presence that is both affordable and attractive to a large group of users. The current NASA plan will result in a manned base that can accommodate international elements, unmanned orbiting platforms, and the development of an operational capability. Inherent in the current revised baseline design is the technical capability for growth of the Station, concurrent with its initial operations, into a configuration with greatly increased capacity to support payloads and provide services to the users.

The Program guidelines encourage U.S. industry investment in the development and operation of the Station. These guidelines are directed to U.S. commercial enterprises which seek to develop with private sector funds Space Station systems and services. The guidelines provide for appropriate incentives as well as protection for commercial proprietary rights. Participating commercial enterprises would retain responsibility for sustaining engineering, operational support, management, financing, and spare parts for their products or services.

Program Definition (Phase B)

A major element of NASA's development strategy for the Space Station Program has been to conduct a comprehensive Program definition phase which drew heavily on past experience in NASA program management and the technical expertise that exists in both the NASA field centers and U.S. industry. The Program actively solicited advice from outside communities on key matters such as user requirements, configuration, program management, evolution, technical risk, safety, commercial and international participation, and projected program costs.

Throughout Phase B, completed in January 1987, NASA involved the user community in all major aspects of the planning process. Mission requirements were solicited from federal, scientific, international, and commercial sources and reviewed by various advisory groups. The user community continues to have representation at all levels of the Program. NASA is sensitive to the need to keep payload procedures simple and timelines short.

NASA believes that life-cycle costs, particularly development, transportation, and operations costs, must be kept to the minimum consistent with crew safety and mission requirements. In the Phase C/D RFPs, NASA has requested that proposals include cost saving approaches which NASA plans to consider in the RFP evaluation process.

A major Program objective is to stimulate technologies of national importance, such as A&R, by using them to provide Space Station capabilities. The FTS is the centerpiece of the Space Station Program's A&R activity. The programs A&R strategy is designed to:

• Apply selected elements of state-of-the-art A&R technologies to increase crew safety, Station productivity, and cost-effectiveness;

• Provide, in the Station baseline, design features for the future application of more advanced A&R during Station evolution; and

• Support the development of advanced A&R technologies that improve Station evolutionary capabilities and transfer appropriate elements of these technologies to terrestrial applications.

The Advanced Technology Advisory Committee reports semiannually to the Congress on NASA progress in incorporating A&R into the Program. NASA has requested in the Phase C/D Requests for Proposals (RFP)s that offerors include in their proposals A&R applications for the Space Station and how they would tailor their design to allow evolution to an expanded A&R capability.

During Phase B the Advanced Development Program funded promising areas of technology applicable to the Space Station. The following discusses the four categories of the Space Station Advanced Development Program:

• Flight experiments of technologies that have demonstrated feasibility during ground test confirm performance in the Space Station environment. A typical example is the heat-pipe experiment that is scheduled to fly on the NSTS.

• The construction and use of ground system test facilities called "test beds" verify the end-to-end performance of distributed systems. A typical example is the Data Management Test Bed at Johnson Space Center (JSC).

• Prototype technology accelerates development of projects that have shown promising breadboard performance but must be successfully tested in a realistic Space Station environment of a flight-like configuration before the design may be applied to the Space Station. A typical example is the two-phase thermal loop.

• Focused technology includes promising, ongoing technology projects that have not progressed to the degree of development where application can be planned but show high enough Space Station application benefit that their development should be accelerated. For example, development of the technology of solar dynamic electric power generation is being given a high priority.

The Phase C/D contractors will be authorized to use the NASA advanced development test beds in accordance with their development contracts. The NASA strategy is to assist the hardware contractors in evaluating technical approaches at minimal dollar and schedule cost. Test beds are located at all Space Station hardware development centers.

Design and Development Phase (Phase C/D)

The U.S. Space Station elements will be developed by four NASA field centers with overall Program direction by the Program Office (Level II) in the Washington, D.C. area. Development will be supported by competitively selected contractor teams. A more detailed description of field center development assignments and management responsibilities is contained in Section IIB, Management Approach.

NASA's development strategy for the Space Station deliberately precluded utilization of a single prime contractor. For a program of such extended duration as the Station, dependency upon one company would not be in the best interest of the government. Moreover, the "work package" approach better utilizes NASA expertise at the field centers and fosters greater competition among U.S. industry. An essential component of this strategy is that NASA would be responsible for the overall System Engineering and Integration (SE&I) of the Program. The work packages have to be tied together. NASA, rather than a prime contractor, will perform this essential task. To assist NASA in this function, the Space Station Program Office has procured the services of a Program Support Contractor (PSC). This contractor, Grumman Aerospace Corp., was competitively selected, for work package assignments were excluded from the Program Support Contract SE&I is discussed later in this report.

In late 1986 and early 1987, prior to the release of the major hardware RFPs, NASA reviewed the Space Station configuration that emerged and the projected Program costs and capabilities. The revised baseline configuration will provide a permanently manned system with pressurized laboratory and living space, accommodations for attached payloads, a polar-orbiting platform, accommodations for potential international elements, and for growth.

Throughout the development process the design will mature to meet Program requirements. The change control process is discussed in Section II B.

Assembly of the Space Station will be done on orbit. Assembly is planned to be started in the spring of 1994 and is currently scheduled to be completed by the end of 1996. The U.S. polar platform is now scheduled for launch in 1995. Future decisions on the next phases will take advantage of accommodations for the evolutionary growth of Station capabilities.

One of the primary objectives of Phase B activities was the retention of evolutionary growth capability for the Space Station. During Phase C/D new requirements associated with evolution of the Program content and capabilities may emerge. At any given point in time, there will be a carefully defined demarcation between those parts of the Program which have been baselined and properly approved for detailed design, development and certification and those which are still under study. Phase C/D contains an initial period of approximately four months for refinement of the design requirements. In this period, all requirements related to the approved Program content are analyzed by the selected contractors and reviewed with NASA management and support personnel. This process will create a potential for change to the baseline but is necessary to assure that the requirements are consistent and are understood by the selected contractors. This portion of the activity will terminate in a formal Program Requirements Review (PRR) 90 days after Contract Start Date (CSD) and will result in the start of detailed design.

The PRR evaluates the status of the Program and defines actions to be accomplished in order to proceed with the detailed design and release of fabrication requirements. The PRR considers Program content, milestones, schedules, and plans; the Work Breakdown Structure (WBS); and unique requirements of potential international projects including technical ground rules, waivers, and agreements with other NASA organizations.

The preliminary design period will respond to validated requirements with layouts of all primary hardware definition of interfaces and detailed fabrication, procurement, test, evaluation, and certification plans and procedures. The Preliminary Design Review (PDR) will be carried out first at the work package level and then at the program level. PDR activities include review of the system design, engineering study results, preliminary test requirements, schedules, and other programmatic requirements. As a

result of this review, Contract End Item (CEI) specifications; layout and assembly-level hardware, software and interfaces; and top-level fabrication and certification plans will be baselined. After the PDR process, the Program will proceed to detailed design, and long-lead-time fabrication and procurement will be authorized.
The detailed design period, in which the bulk of the design and development activity is contained, results in further baselining and puts under configuration control the details of the hardware and software to be fabricated as well as the final test certification requirements at the work package and contractor level. The details of all interfaces will have been incrementally defined and frozen during the detailed design process.

The approach often used for the design and development of advanced space systems involves test articles for development and qualification purposes. Hardware used for these purposes, but not for flight, is called "prototype hardware." In this approach there can be an extensive and severe testing program for the prototype equipment as it is not intended for flight. Furthermore, the flight hardware can be fabricated and assembled as soon as the design drawings are approved, allowing some schedule concurrency between the prototype and the flight article development. In some cases the technology involved permits, or economies require, that the same unit of hardware be used for the entire sequence of design, limited testing, and flight. This is called the "protoflight hardware approach" or "protoflighting." NASA has successfully used both approaches in previous programs and intends a mixed strategy involving both prototype and protoflight hardware for the Space Station Program. The decisions on whether or not to protoflight specific items of Space Station hardware will depend on factors such as technology risk, flight safety, cost differential and schedule risk. These decisions for Space Station hardware development are to be made between PDR and CDR when the details of the requirements and the approaches for hardware development are finalized.

A Critical Design Review (CDR) will be performed for each of the elements. The CDR provides assurance that the detailed designs of flight and ground systems satisfy Program requirements. The primary product of the CDR will be an approved set of engineering documentation defining the design of selected CEIs to be released to manufacturing. As a result of these reviews, authority will be granted to proceed to completion of fabrication and certification of the Station hardware and software. Plans will be finalized for the assembly, checkout, launch, and on-orbit assembly, system verification, and operation.

Near completion of fabrication a Design Certification Review (DCR) will be held. The DCR is a formal technical review to certify design of the CEIs for flight worthiness and manned flight safety. The review will specifically address certification requirements, plans, methods, results, and certification status of flight hardware and software. In this same time frame, the final details associated with pre- and post-launch assembly and checkout will be baselined, and the final plans for validation that the as-built hardware conforms to the as-certified design will be established.

As part of the activity to establish flight readiness, a series of reviews of the operations aspects of the Program, called Preflight Operations Readiness Reviews (PORR), will be performed. These reviews will assure the status of crew and ground support team training, flight and ground console operations, the Space Station Support Complex (SSSC), Program and user support facilities, and the status of NSTS interfaces relative to Station crew and cargo.

The Flight Readiness Review (FRR) will be performed prior to each launch during the assembly phase and will certify the flight readiness of hardware and software. This review will include assembly hardware, crew equipment, Flight Support Equipment (FSE), associated support hardware, payload support equipment, and other elements as specified by the Director of the Space Station Program.

The final step in the development program will be the Operational Readiness Review (ORR) after the on-orbit integration, assembly, and checkout have been completed. As a result of this review, the actual hardware and software performance and capability will be determined, defined, and certified, and the initial detailed operational procedures for the Program at that phase will be baselined.

The total process of system development in phase C/D is depicted in Figure II-1.

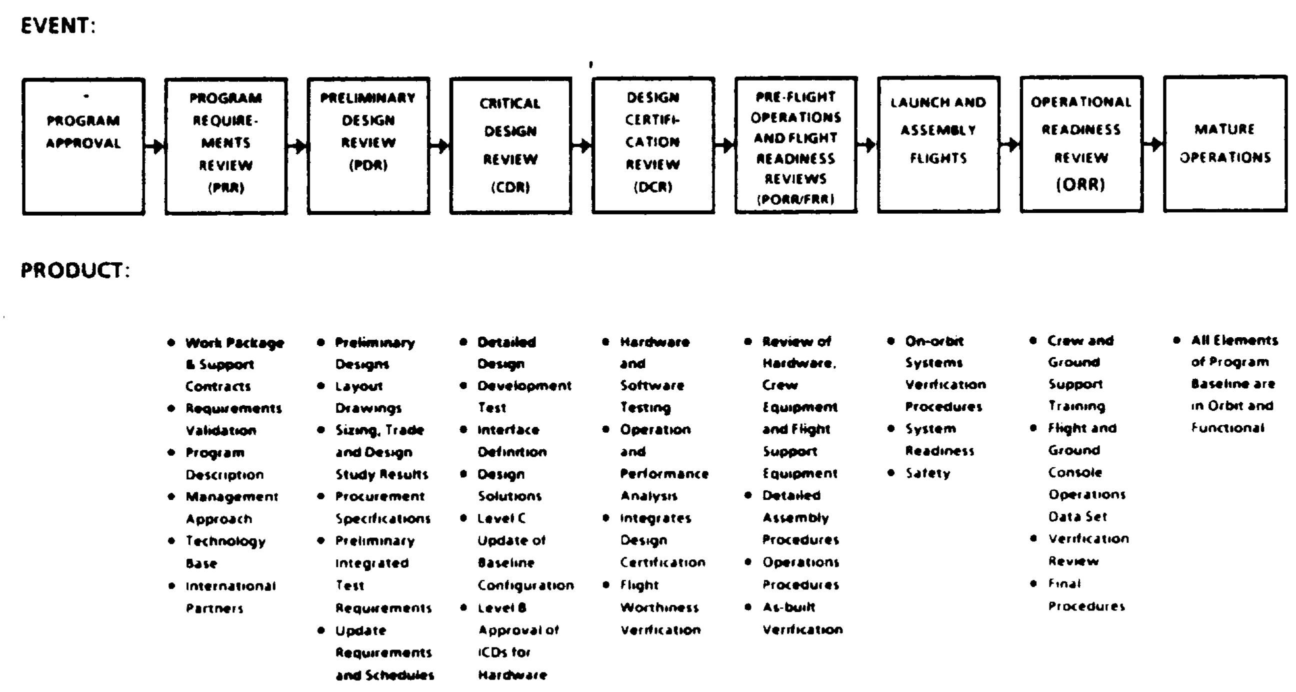

Figure II-1. Space Station Phase C-D Events

System Engineering and Integration (SE&I)

A system engineering approach across the total Space Station Program is essential for developing and maintaining a coherent, technically integrated design. The system design, integration, and verification activities must be carefully blended to assure that the Space Station provides the necessary performance required for safe and efficient operations. The Space Station SE&I starts with the development of the system design requirements which are derived from the needs of the scientific community for new experiments to fly in Earth orbit; the needs of advanced-development programs for data from space to validate promising, new technologies; the need for potential new space manufacturing techniques and commercial products; and other space needs of industry and government.

Space Station SE&I controls the definition of elements and distributed systems which are the fundamental building blocks of the Space Station. An element is the largest functional assembly used as a Space Station building block. The U.S. laboratory is an example of an element. A distributed system is one that is required by two or more elements and provides an end-to-end function. The electric power system is an example of a distributed system.

The SE&I approach to the Space Station must define all of the performance characteristics of elements and distributed systems so that they will fit together in orbit and work efficiently to provide an integrated and functional Space Station.

Space Station Program-level SE&I includes the following: analysis of the overall Space Station performance, optimization of user support, definition of the configuration and its supportability, apportioning the performance requirements among the elements and subsystems, controlling the design process, planning the system integration, and conducting the on-orbit assembly and test. The test and delivery of the elements and distributed systems is performed by the participating Centers or the international partners.

A principal SE&I function is to conduct tests of the assembled Space Station on orbit and to validate and document the "as built" configuration to provide a reference for future maintenance, modification, and operation of the completed Space Station.

Close coordination of SE&I with Space Station Information System (SSIS) and other Program functions assures a balanced design. An example of this balance is in the design, number, and location of the cupolas which are required to facilitate proximity operations, EVA, attached payload activities, and Space Station maintenance.

NASA has defined a strategy for the design, development, verification, integration, assembly, launch, and on-orbit validation of the Space Station systems. This strategy involves the following:

- Verification of all systems and elements prior to launch;
- Commonality of test requirements and procedures across work packages;
- Phase C/D contractor execution of verification testing (mandatory accountability);
- Design of simple interfaces to facilitate verification;
- Design for a minimum of on-orbit assembly;
- Design for maintainability and minimum life cycle costs;
- Commonality across work packages in standards, hardware, and procedures to simplify orbital verification and to minimize cost;

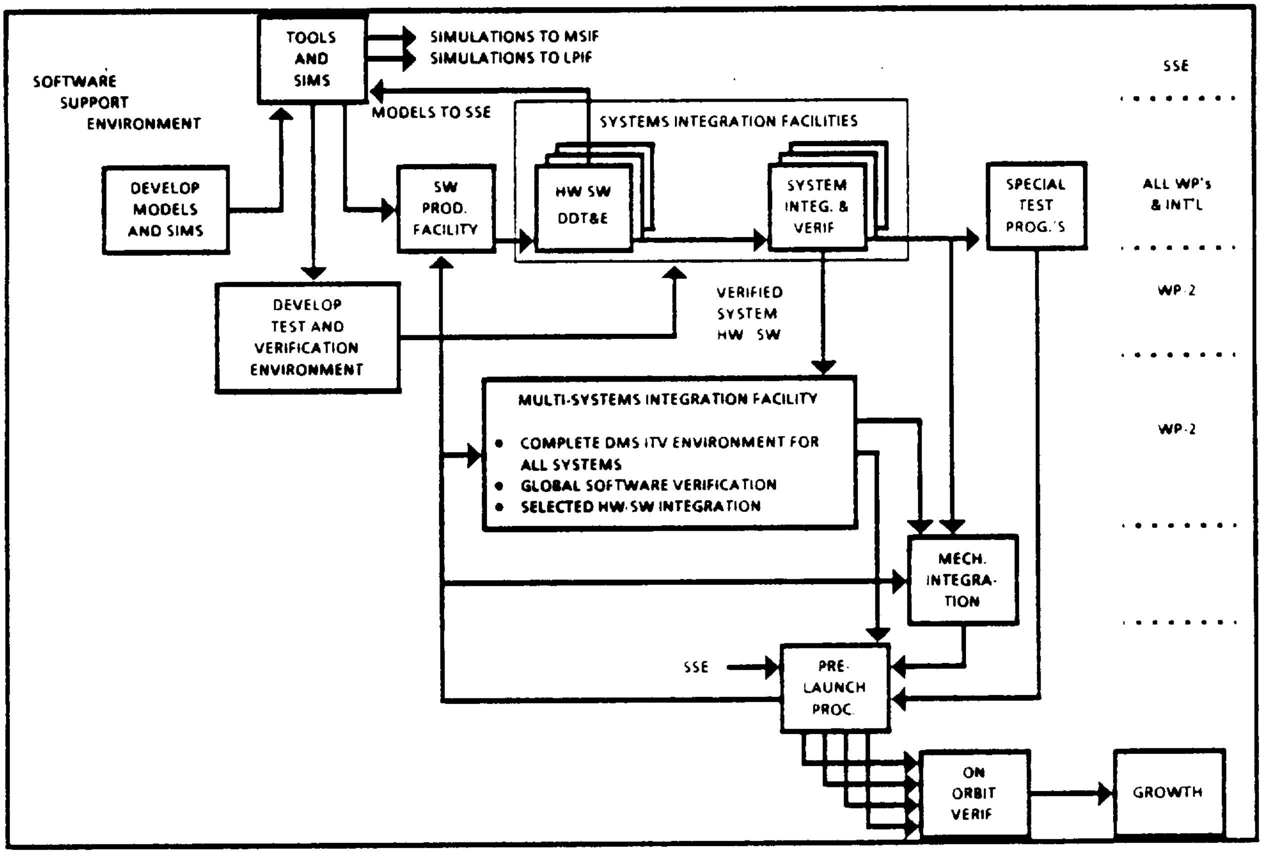

Figure II-2. Multisystems Integration Facility

- Extensive use of simulators to verify interfaces; and
- Early integration of application software into flight hardware.

Some Space Station subsystems will have functional components located in all major elements. The Data Management System (DMS) is one example of these distributed systems. Complete subsystems must be designed, developed, and validated for the incorporation into different modules and other elements. Each module must also be developed, assembled, and tested as an entity. After deployment of each launch package, the partially completed Station must function as a self-contained spacecraft pending mating of the next launch package.

A Multi-System Integration Facility (MSIF) including a transportable simulation capability is planned for the validation of interfaces with simulated external environments. See Figure II-2. Subsystem contractors will develop models and simulators as well as intrinsic subsystems with embedded software for use by other work package contractors and for incorporation into the MSIF. For the integrated subsystems (DMS, Electrical Power, etc.) contractors will design and develop subsystems as dictated by an Architectural Control Document (ACD). The contractor will assure that the end-to-end system is in consonance with the ACD. Field Center Project Offices supported by their contractors will be responsible for validating the functional performance of their elements and will support the integration of the elements with the rest of the Space Station. The element contractor will be responsible for establishing user compliance requirements and for the integration of user hardware. For example, the U.S. laboratory module contractor will have the responsibility of integrating experiments into racks and the racks into the module. The contractors also will participate in the incorporation of elements into launch packages.

At a checkout facility to be developed at the Kennedy Space Center (KSC), launch packages will be fully evaluated prior to launch as well as tested for compatibility with subsequent launch packages. The launch packages will be assembled on-orbit where final integration and validation tests such as the precise measurements of structural-dynamics modes will occur.

The distributed development strategy involving several contractors will require that the Program standarize certain selected processes and procedures. These processes and procedures must be controlled in the same way as design requirements. The mechanism for this control is through Process Requirements which are issued by the Program Office. Table II-1 is a listing of the current process requirements. One of the more important process requirements deals with commonality.

A Space Station Commonality Program has been initiated to reduce Space Station Program operating costs and the crew time required for training, operations, and maintenance. The Program aims at reduced costs by (a) using existing designed hardware from other programs, (b) using identical or similar designs to satisfy similar functional requirements, (c) reducing the types of spares required, (d) using qualified standard parts, and (e) using common software, hardware, and interfaces. The Space Station Commonality Process Requirements document establishes responsibilities within the Program.

SPACE STATION INFORMATION SYSTEM SERVICES ENGINEERING AND INTEGRATION

NASA has placed significant emphasis on the system engineering and integration of the Space Station Program information systems. These systems include the Technical and Management Information System (TMIS), the Software Support Environment (SSE) system, and the operational Space Station Information System (SSIS). TMIS, a ground-based distributed information system, will be connected through the existing NASA Program Support Communication Network (PSCN) and will allow transmittal of development phase engineering and management information between NASA Program organizations and receipt of data by the field centers from their contractors' facilities. The SSE System will be a ground-based information system which provides the tools for the development, maintenance, and sustaining engineering of Program software and will also be connected through the PSCN. The SSIS will be the operational end-to-end system by which the data flow between the onboard system and ground control or data processing systems and the scientific users will be provided. The SSIS will be a distributed system spanning the total information flow networks required to operate the Space Station. The SSIS will operate via the NASA Communications Network (NASCOM). Although TMIS and SSE are primarily developmental support systems, their connectivity with SSIS will permit valuable operational use. These systems are discussed in more detail in the following sections.

Space Station Information System (SSIS)

The SSIS will provide the operational end-to-end command, control, and

Table II-1. Process Requirements

1. Maintainability Process Requirements
2. Commonality Process Requirements
3. Master Verification Process Requirements
4. Combined Elements and Integrated Systems Process Requirements
5. Customer/Experiments Verification Process Requirements
6. Verification Integration Process Requirements
7. System Engineering Process Requirements
8. Automation and Robotics (A&R) Process Requirements
9. Resource Allocation Process Requirements
10. Program Cost Management Process Requirements
11. Support Equipment Integration Process Requirements
12. Interface Development Process Requirements
13. Operations Process Requirements
14. Contamination Control Process Requirements
15. User Integration Process Requirements
16. Mission Manifest Process Definition
17. Ground Support Equipment Integration Process Requirements
18. Space Station Flight Support Equipment and Orbital Support Equipment Integration Process Requirements
19. Electromagnetic Effects Control Process Requirements
20. Plasma Effects Control Process Requirements
21. Ionizing Radiation Effects Control Process Requirements
22. Process Requirements for Design Knowledge Capture
23. Verification and Installation, Assembly, and Checkout Process Requirements
24. Software System Engineering Process Requirements

informational flow infrastructure between the on-board and the ground-based control and data processing systems. The SSIS will service on-board payloads, sensors, and mechanisms with information processing, archiving, retrieval, and exchange. The SSIS integrates all the data systems and information system services functions required to manage information flow within the Space Station; among customers, crew members, and ground support personnel; and between ground-based functions. The engineering and integration task for the SSIS must assure proper functioning of the on-board systems, such as the Data Management System and the Communication and Tracking System with the NASA space and ground-based communication networks, the Space Station manned base and platform control centers, and the space science payload data processing, archiving, and retrieval system. The SSIS represents a major engineering and management challenge that will require extensive Program interaction with the Office of Space Operations and the Office of Space Science and Applications.

The SSIS engineering and integration approach is to provide information services using an end-to-end system. This approach requires defining the information systems services which must be provided end-to-end (including data classes, priorities, and performance characteristics), standards and interfaces to implement those services, selecting standards from existing national, international, and commercial standards to maximize interoperability with other national and international space endeavors, and applying these requirements to the SSIS development process. Assurance reviews of each SSIS element or sub-network for standards compliance will be conducted, as well as element, sub-network and end-to-end testing of SSIS.

Technical and Management Information System (TMIS)

In view of the distributed nature of the Space Station development program and the numerous technical and organizational interfaces, the Program will implement TMIS to improve Program efficiency and data reliability and to support timely decision making. The TMIS will include a backbone data communications network, data processing systems, integrated software tools, and Program-wide data bases which will provide both technical and management users with ready access to information.

The TMIS acquisition strategy is to utilize commercially available, competitively procured products which will not require development of system hardware of software. TMIS will bring on the existing base of NASA data processing and data communications capabilities to achieve maximum return on previous investments. To design, to develop, to operate, and to maintain TMIS, NASA has competitively selected Boeing Computer Services as an integration contractor. The eight-year contract began on June 4, 1987.

NASA intends to use TMIS throughout the life of the Program as the primary mechanism for maintaining, distributing, and archiving controlled data among the three levels of NASA management and the Program Support Contractor (PSC) and to provide information system interfaces with the international partners, the development contractors, and Space Station users. TMIS will be incrementally developed to support the definition, design, development, test, and operational phases of the Space Station Program. Incremental implementation of TMIS will allow NASA to avoid technical obsolescence by incorporating into the TMIS architecture newly emerging technology as it becomes commercially available.

To support the variety of TMIS users, the system capabilities will include project scheduling, resource management and control, requirements development and traceability, configuration management, problem tracking, computer aided design and engineering analysis, design knowledge capture, electronic mail, calendars, documentation, data security, and archival. Using these capabilities, TMIS will provide a repository of Space Station Program-wide management, engineering, design, operational, and user payload information. Program-wide data base requirements for TMIS will be generated by Information Planning Groups.

Software Support Environment (SSE) System

The primary goal of the SSE System is to minimize the operational costs at minimum risk.

Achievement of the minimum cost and risk goal will depend on a software development and maintenance environment (known as the SSE System) that will be standardized for the Program. The major components of the SSE System are the software tools, the SSE Development Facility, and the Software Production Facilities. The SSE Development Facility will be used to develop and maintain the SSE software requirements, design and test tools, compilers, debuggers, models, and simulations. SSE software tools will be used by each Software Production Facility to develop, integrate, and maintain the Program ground and flight software. The SSE System will be developed incrementally with its capabilities time-phased to meet essential Program needs.

The SSE System will provide complete and consistent support for the development, integration, and maintenance of Program software.

Transportation

The Space Station configuration is based on NSTS capabilities for transportation to and from low Earth orbit. The Shuttle launches the elements of the Space Station, provides a stable base from which astronauts can assemble the Station, resupplies the Station through periodic logistics missions, and provides the means for crewmembers to travel to and from the Space Station.

Another space vehicle, the OMV, will be used to provide additional capability to the Space Station Program and to the utilization of the Station. The OMV will be capable of functions which greatly enhance the Space Station including bringing other satellites to the Station for servicing and returning them to their operational orbits and remotely servicing satellites in nearby orbits. The Shuttle carries the OMV to the Station, and after completion of the mission, it returns the OMV to the ground to be refurbished.

NASA is conducting studies of U.S. Expendable Launch Vehicles (ELV)s that would complement the projected NASA baseline of five flights to the Space Station per year in mature operations. The potential role identified for ELVs is the resupply of consumables. Logistic elements launched by ELVs in the future might rendezvous with an OMV that would ferry the logistic element to the Station. ELVs are also being considered for launching polar orbiting platforms.

The assembly sequence described in Appendix A is the current plan. Studies are under way for the use of other vehicles functioning in conjunction with the Shuttle for Space Station assembly.

The addition of attached payloads, experiment equipment for the pressurized modules, spare parts, and expendables will require delivery missions throughout the operational lifetime of the Space Station. The return of manufactured products and equipment for refurbishment will require use of the NSTS. Efforts will continue to minimize these transportation requirements.

Operations Capability

Space Station operations encompass all activities required to assemble and maintain the Space Station and platforms for the planned lifetime. These activities include prelaunch and postlanding processing, crew and ground personnel training, tactical and increment planning, onboard and ground support of station operations, resupply and return logistics operations, communications and data management, trajectory maintenance, and the rendezvous and proximity operations for vehicles and free-flyer satellites. Integration of users with the Program and support to user operations are also provided.

Reviews of flight and ground systems requirements for operations suitability will be conducted in advance of Program design reviews so that their results may be incorporated in decisions and tradeoffs. This is important to ensure that the requirements and design are responsive to the users' needs and that the systems can be operated efficiently and effectively.

In the development phase of the Program, an operations infrastructure will be developed concurrently with the flight hardware and software. This infrastructure will consist of a management structure, a trained work force, and a set of unique support facilities and will be based on recommendations of the Space Station Operations Task Force chartered by the Office of Space Station (OSS). Requirements and design reviews for each facility are planned. Milestones for operations facilities are keyed to the Program schedule for operations.

Space systems operations include the safe operation and maintenance of the Space Station to provide resources and capabilities for users. Planning and real-time support for space systems operations will be provided by a centralized organization supported by engineering and maintenance expertise at the four U.S. WPCs and international partner locations. The Support Services Control Center will be at the JSC. Its capabilities include telemetry processing and storage for systems monitoring and analysis; activity planning and scheduling; resources and consumables management; and trajectory maintenance and maneuver targeting.

The Space Station Support Center (SSSC) will be supported by Engineering Support Centers (ESC)s at the work package centers. During on-orbit verification the centers will have a real-time support capability to monitor and analyze hardware and software; to support the SSSC in troubleshooting problems; to develop maintenance procedures; and to perform sustaining engineering.

User planning and integration activities are distributed throughout many countries, government organizations, private companies and universities. For near-term planning and real-time operations, user activities are coordinated and supported by a Program organization. The Payload Operations Integration Center (POIC) at the Marshall Space Flight Center (MSFC) will have the capability to support various levels of computerized payload planning and will serve as the users' interface to the SSSC. Users and user sponsors will develop their own infrastructure.

The Space Station Platform Support Center (SSPSC), to be at the Goddard Space Flight Center (GSFC), will perform the POIC and support functions for the platforms under funding by other Programs.

Prelaunch processing of hardware elements of the Space Station and platforms and logistics carriers will be carried out at the launch site. Post-landing operations for logistics carriers and cargo is a responsibility of the launch center. The Space Station Processing Facilities (SSPF) will be located at KSC with capabilities for integrating and testing system elements and payload-to-system element interfaces. Payloads and Station cargo will be physically integrated with the logistics carriers here.

Integrated logistics planning will be conducted at the launch site with logistics management being the responsibility of the work packages and contractors. A phased transfer of logistics management responsibility from the developing center to the launch site will take place. Existing facilities at KSC will be used initially for logistics operations. A logistics information system will be developed to support them. A capability to support logistics operations after logistics management responsibility transfer is planned, and it will include such items as inventory management, automated test equipment, and repair capability.

Numerous capabilities for crew training will be used. These capabilities include part-task systems trainers, manipulator and proximity operations simulators, one-G mockups and trainers, and neutral buoyancy facilities. The Space Station systems operations, manipulator and proximity operations, and ground controller training will be centralized at the Space Station Training

Facility (SSTF) at JSC. The SSTF will have the capability to train crews and ground controllers for nominal Space Station systems proximity and manipulator operations as well as response to off-nominal situations. The trainers and simulators will be linked together with NSTS facilities to conduct nominal and contingency integrated simulations during assembly. Joint onboard and ground integrated simulations may be conducted during mature operations phases to maintain crew and ground controller readiness.

Space Station Evolution

With a useful life spanning decades, the Space Station will experience many changes. Commercial, scientific, and technology users will better understand the long term advantages of the space environment on experiments and manufacturing processes and will likely require enhanced Station capability. Some user needs may diminish; others will increase, and still others may be entirely new.

In examining this process, NASA concluded that the Space Station must be designed and constructed in a manner that allows response to changing user needs. Evolution of the Station comprises those changes that increase its capability to meet user needs. This increase can occur in physical growth of the structure, more modules, more laboratory space, more accommodations for attached payloads, or increased productivity and efficiency of Space Station systems and subsystems.

Specific design provisions or "scars" will be incorporated to allow increases in resources and the addition of new functional capabilities. Flexibility for growth will be a major factor in decisions on the Space Station configuration as well as system and subsystem designs. Whenever possible, system and subsystem designs that facilitate the later incorporation of new technologies will be selected. An evolutionary, advanced technology program has been established to develop technologies that will increase Space Station productivity and support expansion of the Station capabilities.

B. MANAGEMENT APPROACH

Management Overview

The Space Station Program will use a three-tiered management structure. The three levels are as follows: Level I, the Office of the Associate Administrator for the Office of Space Station (OSS) at NASA Headquarters in Washington, D.C.; Level II, the Space Station Program Office in nearby Reston, Virginia; and Level III, the field center Project Offices. This structure is shown in Figure II-3.

The Associate Administrator for the Office of Space Station at NASA Headquarters, Level I, is responsible for the overall management and strategic planning of the Program. The organization of this Office is shown in Figure II-4. Principal management responsibilities include policy direction, budget formulation, external affairs, and Space Station evolution. The Associate Administrator will establish and control Level I technical and management requirements, milestones, and budget allocations and forecasts. Coordinating external affairs with both legislative and executive branches, user communities, international partners, and NASA Headquarters that support the Program also falls under the jurisdiction of the Level I Office of the Associate Administrator.

The Space Station Program Office, Level II, (Figure II-5) is responsible for development of the Space Station and the operational capability of flight and ground systems and the control of internal and external interfaces. Principal responsibilities include system engineering and analysis, Program planning and resource control for both development and operations phases, configuration management, and integration of elements and payloads into an opera-

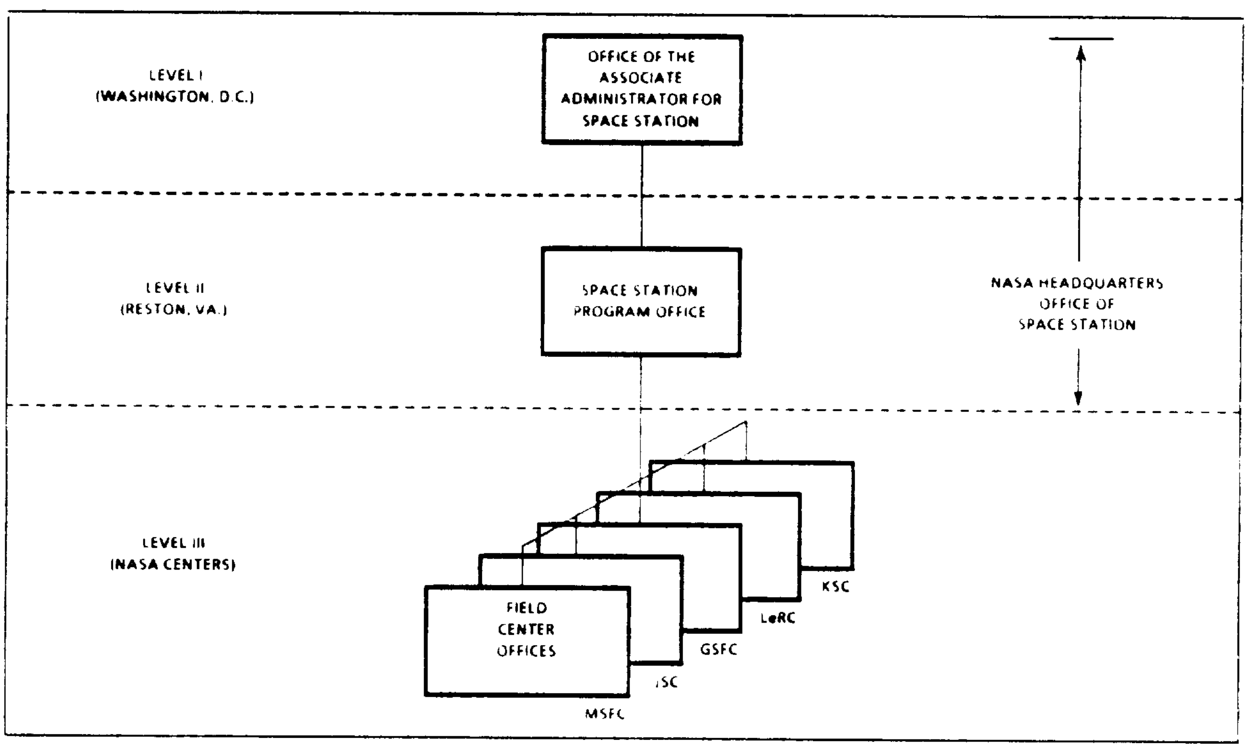

Figure II-3. Space Station Organization

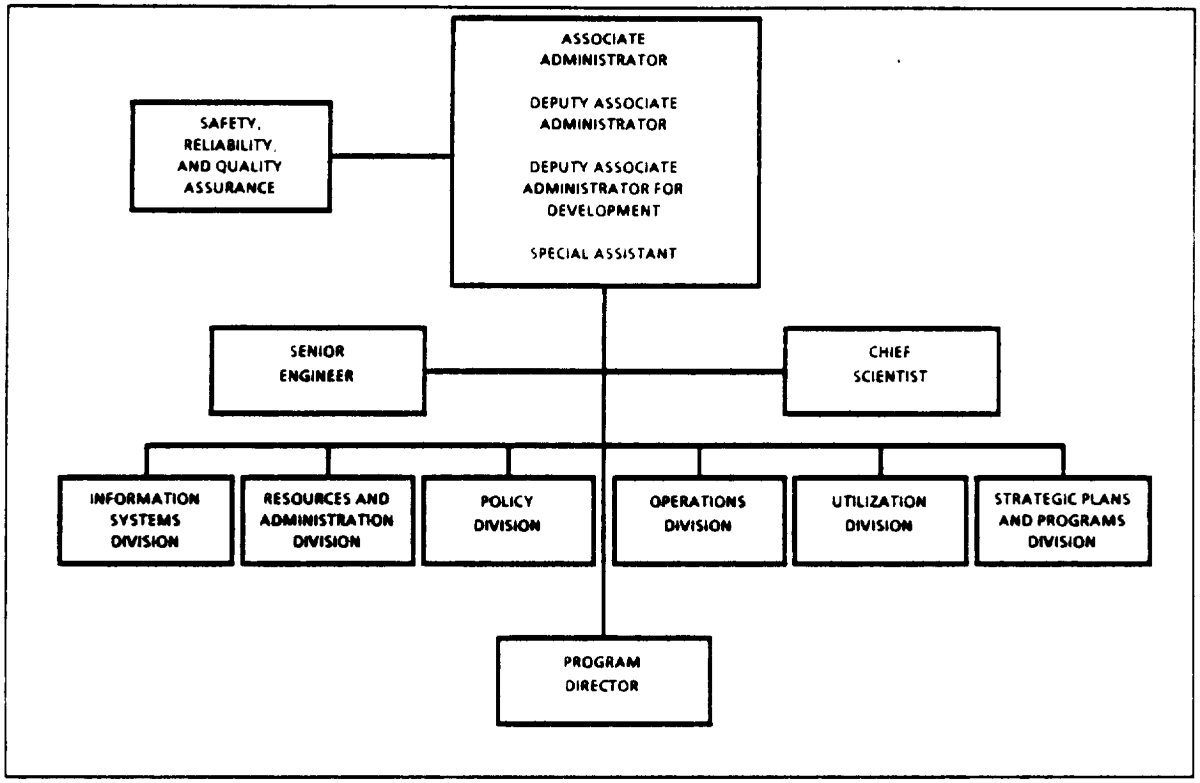

Figure II-4. Office of Space Station Organization

ting system. This Office is headed by the Director, Space Station Program, who is responsible for the day-to-day management. The SSPO is assisted by the PSC and by the TMIS and SSE contractors. The Jet Propulsion Laboratory (JPL) provides an independent Program requirements and assessment function.

Level III consists of the various field center Space Station Projects Offices. These Offices are responsible for Design, Development, Testing and Evaluation (DDT&E); operation of hardware and software systems; and element, evolution, and engineering support. The Project Managers of these Offices report to the Director, Space Station Program.

Center Directors advise the Associate Administrator, Office of Space Station, on technical and management issues and assure institutional excellence and support for their portion of the Program. They also participate as members of a Space Station Management Council. This Council meets regularly with the Associate Administrator and the Program Director on programmatic and institutional matters.

While the SSPO is an organizational element of Headquarters, it is physically separated from the Office of Space Station. While the Associate Administrator has overall Program responsibility, the activities of the Level I Office focus largely on external functions. Examples include international policies, budget development and defense, and congressional activities. On the other hand, the responsibilities of the SSPO are generally internal, relating to implementation of the Program. Examples include design reviews; configuration change and budget control; and development, test, and verification procedures.

Work Package Center (WPC) Responsibilities

In 1986, General Samuel Phillips, former Apollo Program Director, chaired a committee to review the Program's overall management structure and work package responsibilities. The Phillips Committee recommendations were structured to maintain contractor accountability for the planned Phase C/D. Accountability is essential to cost control and demands clearly definable deliverable items that can be integrated and checked out independently. It also requires the assignment of the entire design and development responsibility for each deliverable item to a single contractor.

The Phillips Committee recommended the following development assignments to each work package:

-All pressurized modules, nodes, and tunnels to WP 1, MSFC;
-The truss and its associated systems to WP 2, JSC;
-The platforms and servicing facility to WP 3, GSFC; and
-The power modules and power management system to WP 4, Lewis Research Center (LeRC).

These assignments resolved issues regarding overlap and duplication of work by placing the WP 1, MSFC contractor in the role of the single module developer and the single module integrator for the Program.

Because the assignment of the habitation module to WP 1 caused a skill mix problem within NASA, the committee recommended that WP 2, JSC provide technical direction to WP 1, MSFC contractor for the design and development of Man Systems. This recommendation solved the NASA skill mix issue and made optimum use of the existing institutional facilities and test beds without diffusing the accountability of the WP 1, MSFC contractor for producing a fully outfitted habitation module.

Further review in the fall of 1986 resulted in a refinement to the field centers' development responsibilities which had been recommended by the Phillips Committee. The following is a summary of the current work package

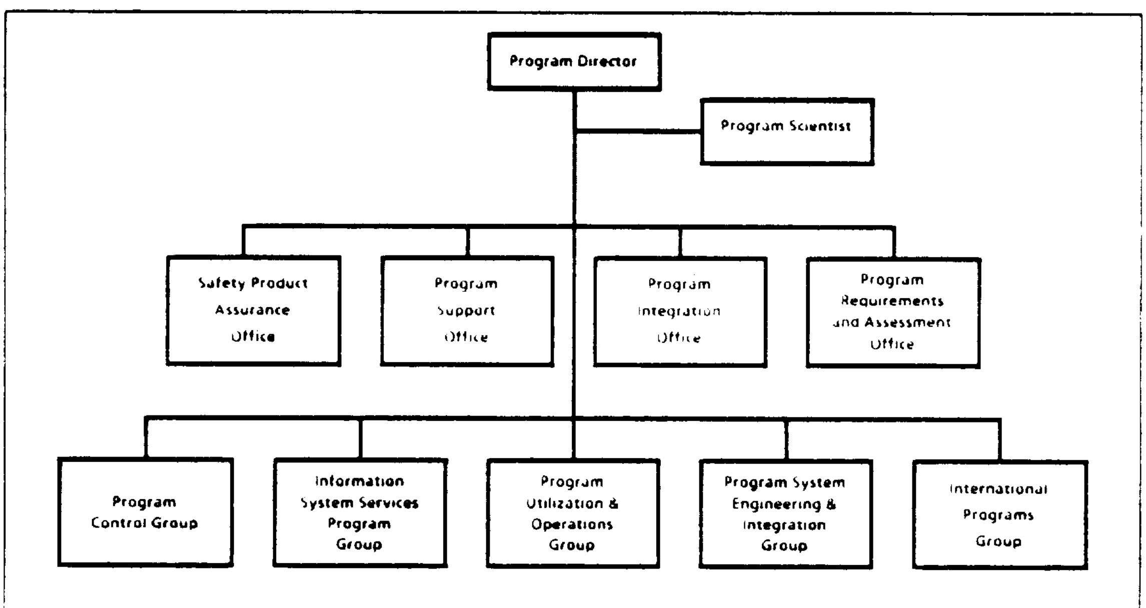

Figure II-5. Space Station Program Office assignments: The responsibility for the Station laboratory, habitation module, logistics elements, and the resource node primary structure fabrication is assigned to WP 1, MSFC. The external truss, distributed subsystems, EVA systems, airlock and resource node design and outfitting are assigned to WP 2, JSC. Responsibility for Space Station platforms, attached payload accommodations, the Flight Telerobotic Servicer (FTS), and NASA's role in servicing is assigned to WP 3, GSFC. The power system is assigned to the WP 4, LeRC. WP 1, MSFC, through its contractor, has overall responsibility for the Space Station laboratory and habitation module. WP 2, JSC continues to exercise its responsibility for the manned space subsystems through special provisions within the MSFC contract. Similar provisions are established in the JSC contract. Technical and management responsibility for the engine elements of the Space Station's propulsion system rests with WP 1, MSFC.

Centers responsible for a distributed system issue a system design in the form of an ACD which guides other centers (Table II-2). These ACDs are under Level II documentation control.

In the Space Station Program, system integration is managed by the Level II office which assures that all subsystems will fit together and function as a single unit.

The SSPO was established to provide strong, central program management to conduct system integration and resolve differences among centers. A control board system, discussed in more detail below under Change Control, has been implemented to review and approve all system documentation to the Program baseline including interfaces shown in Table II-3. The review process includes consideration of design options, technology risk, supportability, safety, and both development and operations costs. Each Level II board has a responsibility in the overall cost management process.

International

Management of the potential international elements will be conducted within the framework of both bilateral inter-governmental agreements and agency-to-agency Memoranda of Understanding (MOU)s which are currently under negotiation. The management structure will be set forth in these agency-to-agency agreements. Documentation plans and major reviews are specified therein. Potential international partners will be technically and financially responsible for Space Station hardware. Management mechanisms will be established to coordinate activities of all partners and to reach agreement on requirements.

Bilateral Program Coordination Committees (PCC)s, established during the

Table II-2. Architectural Control Documents

1. Electric Power System
2. Data Management System
3. Thermal Control System
4. Communication and Tracking
5. Guidance, Navigation, and Control
6. Environmental Control and Life Support System
7. Extra-Vehicular Activity
8. Man Systems
9. Fluids
10. Assembly and Maintenance
11. Servicing

definition phase, will meet during the design and development phase to review respective design, development, operation and utilization activities. At that time decisions will be made to assure implementation of the cooperative activities of the international partners. The Associate Administrator for Space Station and his international counterpart will co-chair each PCC. The co-chairs will each designate their respective members. Joint PCC meetings may be held when specified issues require consideration by another partner at that level.

Liaison activities with international partners will be conducted under the direction of the NASA Office of the Associate Administrator. Under the terms of applicable agency-to-agency MOUs, each partner may provide representatives to the OSS, located at NASA Headquarters in Washington, D.C., to coordinate cooperative Program activities. Likewise, NASA is entitled to such representation at the respective partner's Headquarters sites. To facilitate the implementation of the cooperative program, each partner will provide, under the terms of applicable agency-to-agency agreements, liaison representation at the Space Station Program Office site in Reston, VA. Likewise, the SSPO will provide liaison representation at the respective partner's Program Office. As required on a case-by-case basis, partners may provide liaison representation to specific Space Station Program field office sites to support the implementation of the cooperative program. NASA may also provide, where required, liaison to partner field office sites.

Table II-3. Program Interfaces

ELEMENT/ELEMENT INTERFACES

1. Node/Modules
2. Attached Payload Accommodations/Truss Assembly
3. Service Facility/Truss Assembly
4. Power Module/Truss Assembly
5. Module/Truss Assembly
6. Telerobotic Servicer/Space Station
7. Logistics Carrier (Pressurized)/Space Station
8. Logistics Carrier (Unpressurized)/Space Station
9. Element/KSC Facility
10. Element/KSC GSE
11. Element/FSE

INTERNATIONAL INTERFACES

1. JEM Elements/Space Station
2. Columbus Laboratory/Space Station
3. MSC/Transporter
4. MSC/Space Station
5. MSC Maintenance Depot/Space Station

EXTERNAL PROGRAMS INTERFACES

1. NSTS/Space Station
2. OMV/Space Station
3. GPS/Space Station
4. TDRSS/Space Station

Program Control

The elements of program control which include schedules, resources, and configuration control will be implemented by the SSPO and the project offices.

The management of schedules will be implemented through the establishment of controlled milestones at various levels of the Program. Each controlled milestone will be assessed on a continuous basis by the field center project offices and the SSPO. Any change to the controlled milestones will require formal approval. The Program has established an intersite delivery schedule between each of the implementing project offices. These establish when specific hardware is required to be delivered from one project office to another to meet schedule milestones. These intersite delivery dates are established by the Space Station Schedules Working Group chaired by the SSPO with representation from each of the field center project offices. This group will review the intersite delivery schedules on a continual basis to assess potential problem areas and required adjustments.

All contracts of $25M or greater will have in place a Performance Measurement System (PMS). The PMS will provide the capability to assess the contract performance for both cost and schedule on a monthly basis.

The management and control of financial resources will involve several processes. Management has established a baseline for budget and schedules for the development phase. A detailed phased operating plan will be developed for the operating year, and Program progress against the plan will be reviewed on a monthly basis. The field center project offices will provide cost status and schedule progress to the SSPO. The SSPO will assess the projected budget requirements quarterly and semiannually with the field center project offices. Based on this review the Program Director will make recommendations to the Associate Administrator on the development and operations budget. The recommendations form the basis for the review with Agency management and subsequent budget submission to OMB and Congress.

The SSPO will also review technical changes submitted to the configuration control process for their impacts on development and operations costs and schedule.

The integration of the schedules and cost will be accomplished by utilizing the Development WBS which has been baselined for the Program. There will be an updated WBS based on the data to be provided by the development contractors.

Change Control

The change process will be handled at each level through a formal documentation and board structure.

Top level Program requirements are established by Level I and documented in the Program Requirements Document. These requirements will be controlled by the Program Control Board chaired by the Associate Administrator. Level II program and technical requirements including content, schedule, and interface requirements are contained in the Program Definition and Requirements Document and related sub-tier documents. These documents add technical detail to the Level I requirements. The process for establishing and controlling these documents is founded on a formal configuration management discipline using a Level II Space Station Control Board (SSCB).

The SSCB is chaired by the Program Director. Membership includes the

SSPO functional directors, the Level III Project Managers, other key managers, and the international participants. In practice, the board becomes the top-level authority for reviewing and controlling the Program baseline. The Level II SSCB is supplemented by other SSCB chartered boards and panels to handle work activity in various areas. See Figure II-6. Formally controlled, SSP Level II baseline documentation will be maintained by the SSPO. Proposed additions or changes to the baseline will be made through Space Station Program Level II change requests signed by an SSCB member or the member's authorized representative and forwarded to the SSCB Executive Secretary. The Level II Screening Group, chaired by the SSCB Executive Secretary and comprised of representatives from the SSCB member areas, will review all change requests for completeness, determine the appropriate method for processing, and designate the SSCB member organizations whose evaluations are considered mandatory for change request disposition. The Screening Group Chairman will assign and forward change requests to the appropriate sub-board for evaluation and/or disposition. Change requests deemed within the scope of the board charter may be processed outside of the board in accordance with pre-established criteria or may be dispositioned by the board chairman at a scheduled meeting. The Chairman may recommend that the change request be processed outside of the board in accordance with pre-established criteria or may be dispositioned by the board

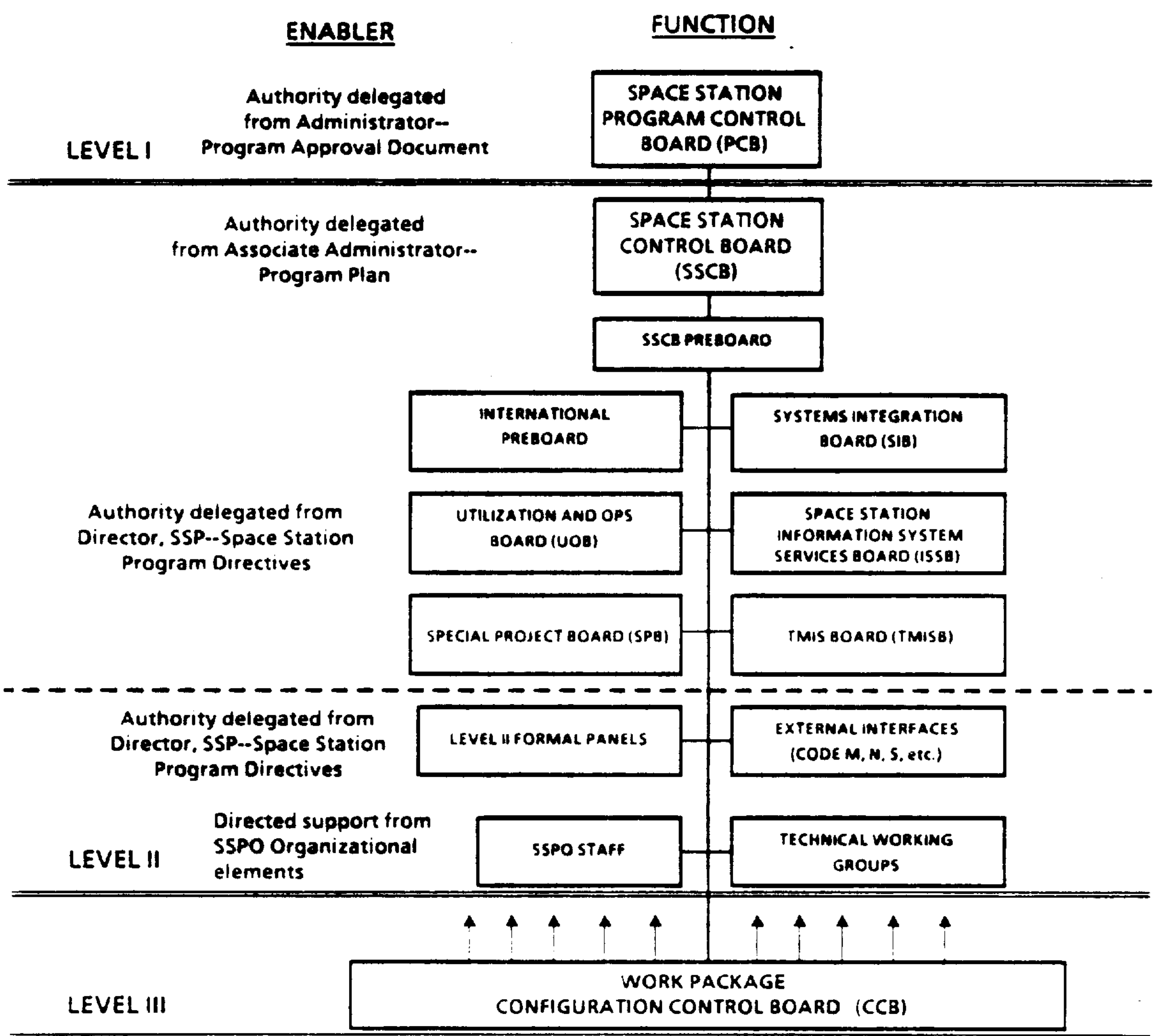

Figure II-6. Space Station Control Boards Structure/Interfaces chairman at a scheduled meeting. The Chairman may recommend that the change request be processed through another authorized board or may forward the change request to the SSCB Chairman for review and final disposition. In the event that the board chairman recommends processing through another authorized board, the change request will be submitted to the SSCB Executive Secretary with the appropriate recommendation. The SSCB Executive Secretary will again provide the change request to the Level II Screening Group with a recommendation for redirection. The Executive Secretary of the board shall be responsible for preparing and distributing minutes and directives and updating the action item tracking list. The change process is depicted in Figure II-7. At each field center Level III project, a similar process is in place with the Project Manager chairing a Configuration Control Board (CCB) to control changes within the project.

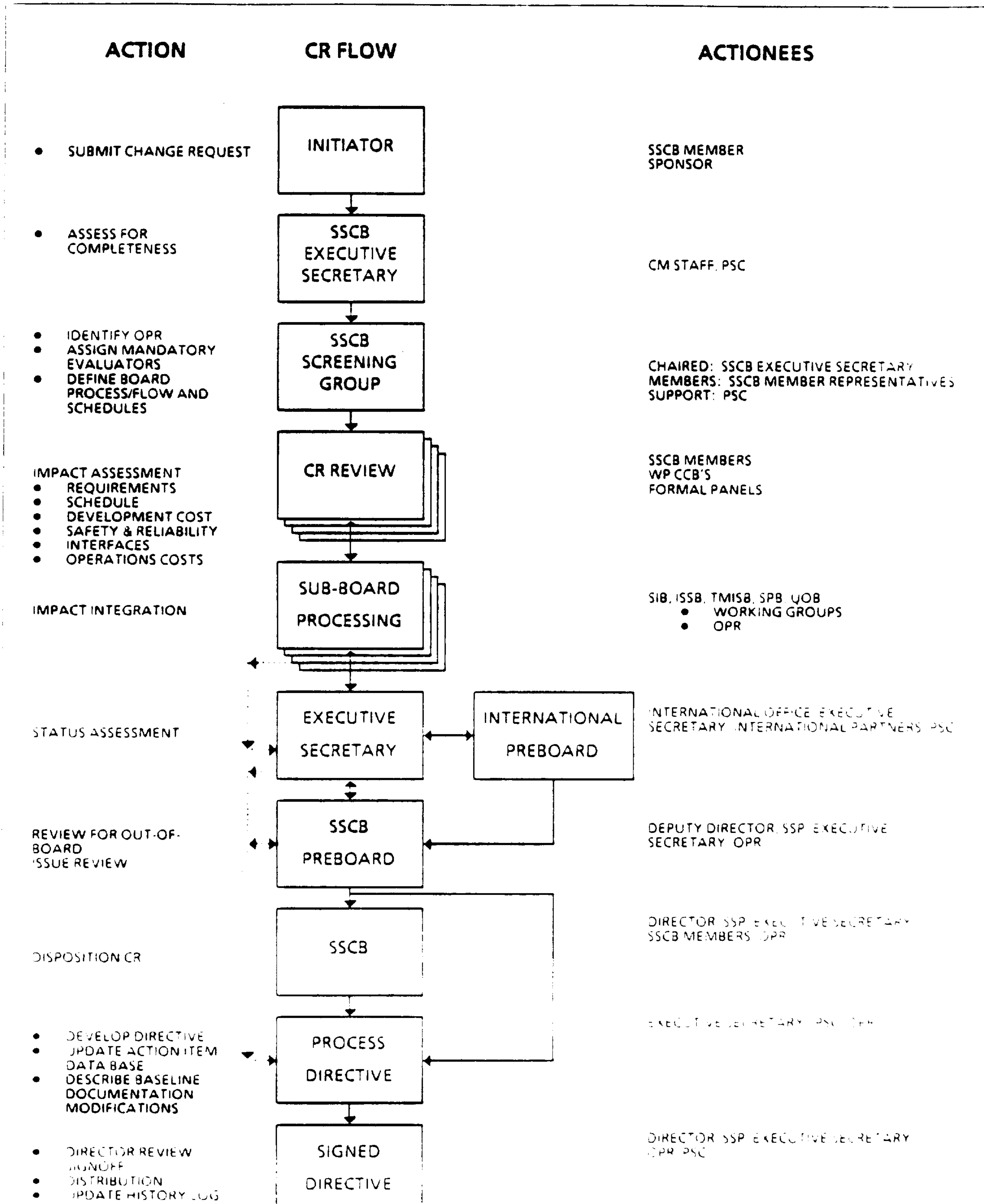

Figure II-7 Space Station Change Request Process

The Program Support Contractor (PSC)

NASA has recently awarded a level-of-effort, task-order contract to provide necessary skills to support the Space Station Program Office in Reston, VA and at the participating field centers. The scope of the contract is broad and includes support in both programmatic and technical activities in all Level II functional areas. The principal effort, however, will be to assist NASA in the essential SE&I functions, including program requirements analysis and assessment, systems engineering and analysis, distributed systems integration, technical integration, and element and launch package integration. The PSC will provide additional support to areas such as design of the ground communication and the ground-to-space communication links, the planning of interfaces with users, and the development of concepts and facility plans for the use and operation of the Space Station.

A Contract Administrator has been assigned to the SSPO to manage the PSC. Task monitors have been assigned in each functional area of the SSPO. The contract duration extends one year after completion of on-orbit assembly. To motivate PSC performance, the contract contains provisions for periodic evaluations and award-fee determination by NASA. The PSC will establish its principal operating site in close proximity to the SSPO in Reston, VA and will have offices at each of the participating centers.

Operations Management

Because of the breadth, duration, and international nature of Space Station operations, a unique organizational structure has been recommended for the effective management of utilization and operations activities. Its primary feature is a strong, centralized, technically competent operations planning and integration activity (Figure II-8). The activities will be strategically managed and tactically integrated in Washington with international participation, and supported and implemented at the centers.

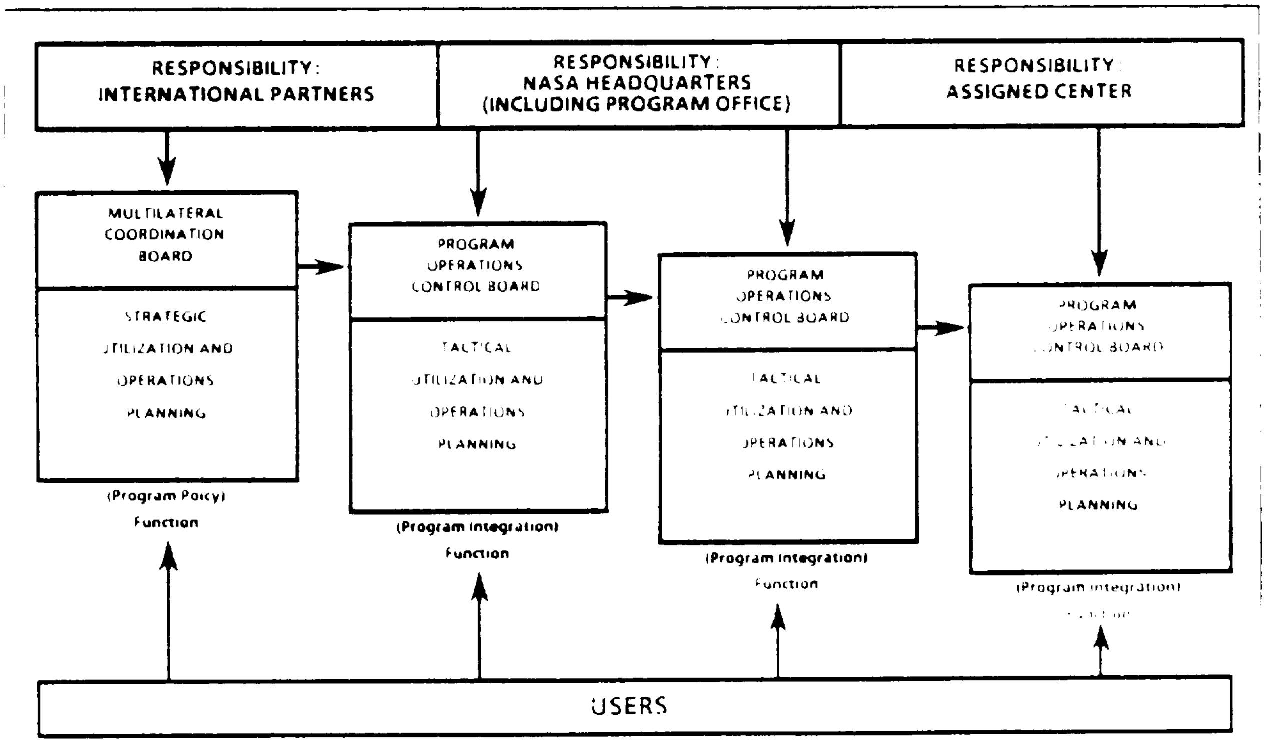

Figure II-8. Operations Management

For the U.S. allocation of Space Station resources, the Space Station Users Board (SSUB) will conduct utilization and operations planning for five year periods. The Board will include membership from NASA user sponsoring organizations (OSSA, OAST, OCP, etc.), other government agencies, and commercial reimbursable users. Each Space Station partner will submit its five year plan. The Multilateral Control Board, supported by the User Operations and System Operations Panels (established by MOUs) will produce a five year Consolidated Utilization Plan (CUP).

The CUP is then used by the SSPO to generate a two-year Tactical Operations Plan (TOP) (Figure II-9). Tactical operations planning covers a two year period and includes manifests, milestones, payload integration, safety reviews, documentation, installation, test, checkout procedures, ground flow, and logistics support. The development of the TOP will be supported by a Space Station Users Working Group and other Station accommodations working groups. A Payload Accommodations Manager (PAM) will be assigned to each payload in the CUP. The PAM will be a single point of contact for an individual user of the Space Station. The approved TOP is the basis for the generation of multiple increment plans, where an increment is defined as the period of time between NSTS visits to the Station (Figure II-10). NASA field centers, international partners, and user operations facilities execute the increment plan as well as support the integrated tactical management functions.

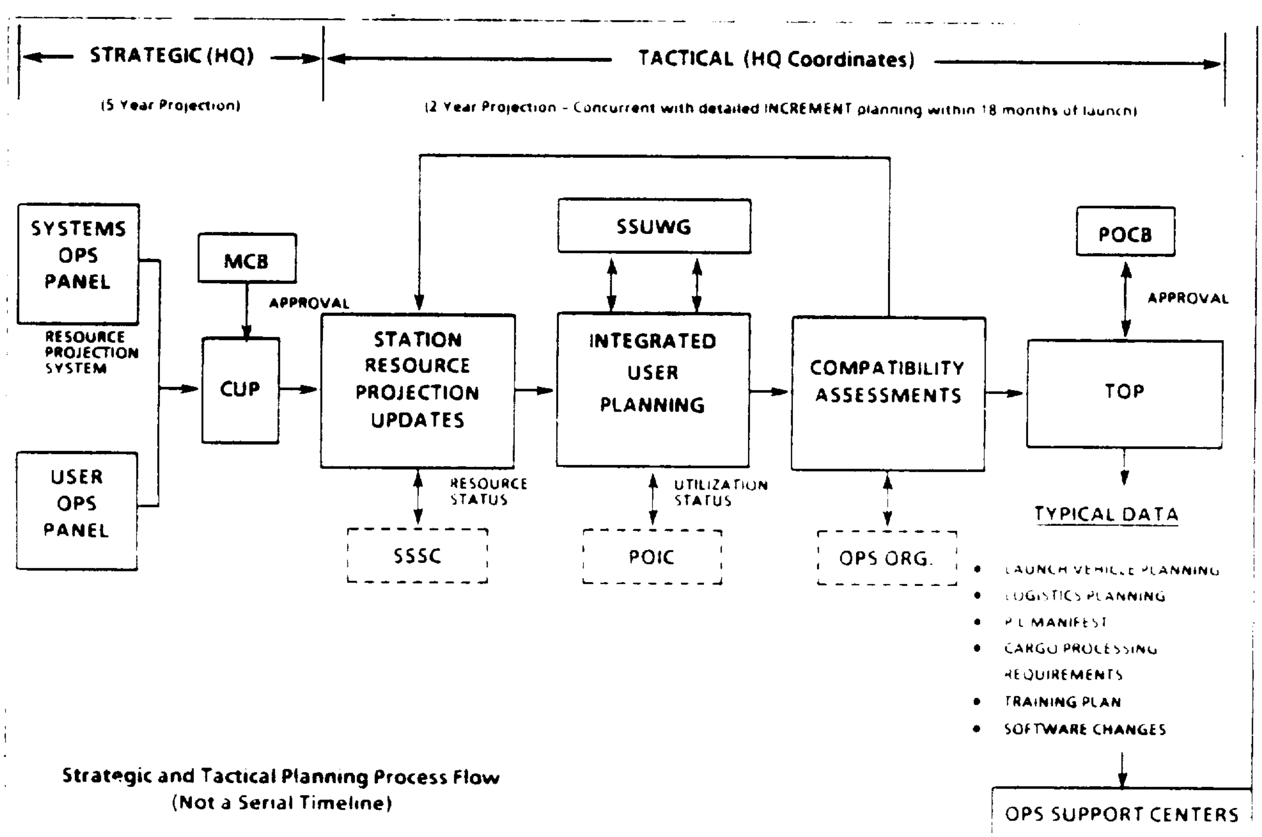

Figure II-9. Operations Planning

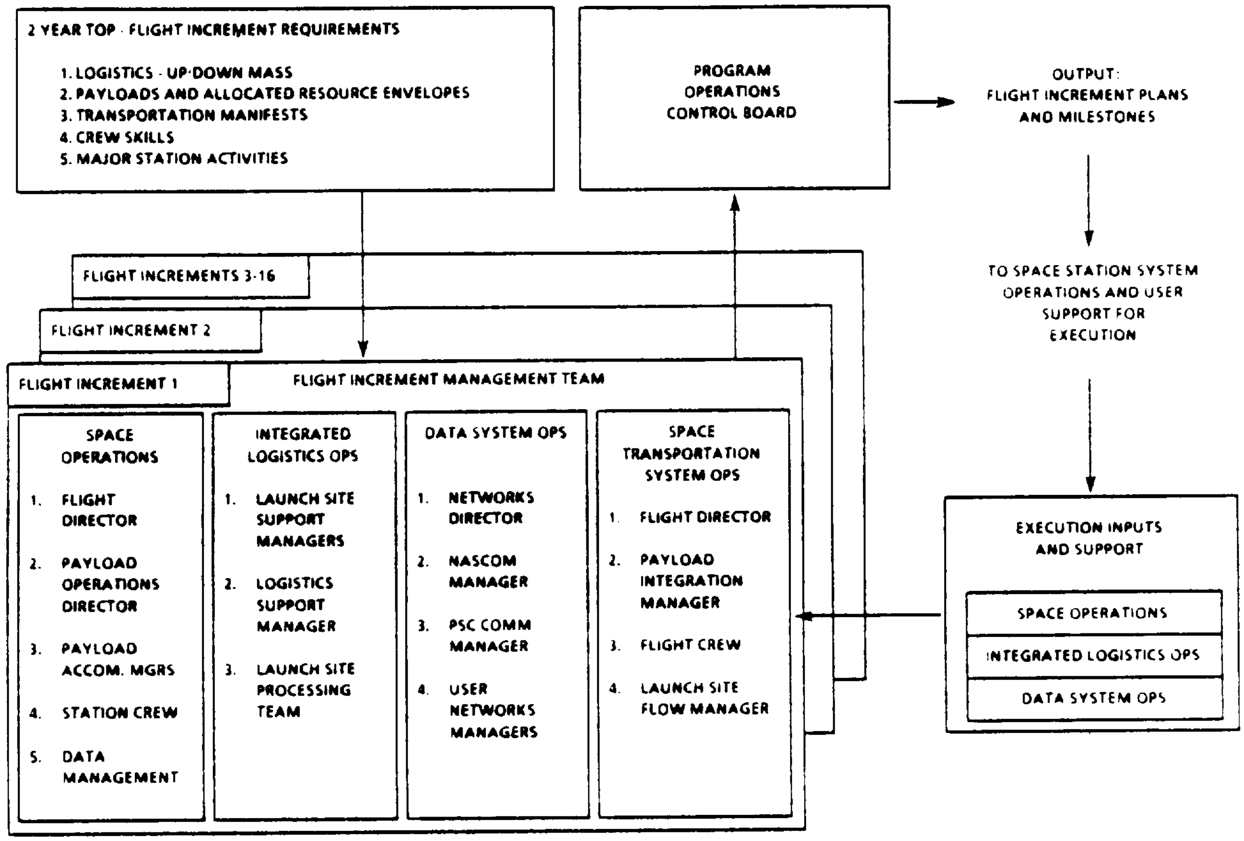

Figure II-10. Increment Planning

Operations Cost Management

NASA recognizes that cost-effective operation of the Space Station, both manned base and platforms, is essential. A plan for managing operations costs has been prepared and is being submitted separately to the committee on Science, Space and Technology. Key features of the plan are an organizational structure facilitating operations cost management; identification and control of significant cost drivers; implementation of tools, procedures, and processes for managing costs; and innovative, evolutionary application of A&R. A clearer focus on operations costs is being provided through the establishment of a separate line for operations in the Space Station budget. A model has been developed to estimate categories of operations costs (e.g., logistics, ground operations) and will be used to predict and assess the effect of Program changes on operations costs. A control board system that reviews and approves all changes to the Program baseline has been implemented. The review process includes consideration of design options, technology risk, supportability, and both development and operations costs. Each Level II board has a responsibility in the overall cost management process.

Construction of Facilities (CoF)

Facility construction requirements are submitted by the field centers to the Space Station Facility Review Board which is chaired by the SSPO with representation from the project offices. This board provides recommendations to the Director, Space Station Program, who provides a complete facility program recommendation to the Associate Administrator, Office of Space Station. The Program priorities are then tied with the agency priorities.

Table II-4 identifies the planned facility projects through FY89. The Program annually reviews requirements for out-years and adjusts its facility project recommendations to meet programmatic changes.

Management Reviews

At Level I a monthly Program Review is held along with regular meetings of the Space Station Management Council. The NASA Administrator conducts a monthly General Management Status Review. This series of reviews is designed to keep management fully informed of both progress and problems and to provide information for timely decisions.

Monthly reviews are routinely held at Level II and Level III Program organizations having responsibility for the development and control of a delegated portion of the NASA baseline configuration to ensure that all higher level and interface requirements have been incorporated into the baseline. These reviews provide management an opportunity to assess progress and to initiate actions to correct problems that arise.

Table II-4. Office of Space Station

CONSTRUCTION OF FACILITIES PLAN

PROJECT	LOCATION	START (FY)
Human Performance Research Laboratory	ARC	1987
System Integration and Mock-up Laboratory	JSC	1987
Space Power systems Laboratory	LeRC	1987
Mods to TS300 for Oxygen/Hydrogen Test	MSFC	1987
Space Station Processing Facility	KSC	TBD
Mission Control Center Addition (SSCC)	JSC	TBD
Simulator-Trainer Addition (SSTF)	JSC	TBD
Automated Integration and Assembly Facility	JSC	TBD

C. PROCUREMENT APPROACH

Background

NASA strategy for procurement emphasizes competition and phasing. Separate Space Station procurements were conducted for Phase A (Requirements and Architecture) and Phase B (Definition and Preliminary Design). At present a competitive procurement is under way for Phase C/D (Detailed Design and Development). During the Phase B development of requirements and conceptual design, competitive procurements were awarded for eight, fixed-price contracts. NASA awarded two concurrent 21-month contracts for each of four work packages managed by NASA field centers. NASA awarded a number of contracts for technology development in a Program termed "Advanced Development." Overall development strategy for the Space Station included a major effort in technology concurrent with the preliminary design. Four key activities were emphasized: focused technology, prototype development, test beds, and flight experiments. Candidate technologies from the advanced development program have been evaluated and incorporated into the procurement process for the development phase.

Strategy

In planning the transition from definition to development, NASA decided to recompete the contracts for the four WPCs rather than "down-select" from among the Phase B contractors. This approach allowed NASA an opportunity to evaluate more thoroughly the results of Phase B and to refine the plans for Phase C/D.

The procurement strategy for the Program development phase is designed as a distributed program consisting of four work packages. Four work package RFPs were released in April of 1987, and proposals were received in September. They are now under evaluation. Each RFP calls for bids against the Program and a phased option with a description of how private sector investment would be integrated with the baseline activity.

The distributed work package approach allows for wide participation by U.S. aerospace industry. Contractor teaming for the different work package elements and systems expands private-sector involvement and broadens resources available to the Program such as the capital investment into aerospace facilities and peripheral areas.

As noted earlier, the absence of a prime contractor and the retention by NASA of the primary responsibility for SE&I avoids the necessity for a long-term contractual commitment with a major Program hardware systems contractor. In-house SE&I makes good use of NASA technical skills and capabilities to build into the agency the corporate memory necessary to manage the Program. NASA in-house integration also minimizes the possibility of duplicating design and development costs while more fully integrating NASA-wide technology and research and development expertise.

The development phase includes eight major procurements. In accordance with federal procurement procedures, opportunities for small businesses and minority-owned enterprises are available. The eight development procurements, some of which have been concluded, are as follows:

(1) a work package design and development contract to be awarded by each of the four WPCs, (2) a TMIS contract that provides common access to the Program data base, (3) an SSE contract that provides the set of tools to be used for life-cycle management of all Space Station software, (4) a PSC to provide

support across the program during Phase C/D, and (5) an FTS contract. All of these contracts are planned to be of the cost-plus-award-fee type except the FTS which for Phase B will be on a fixed-price basis. The NASA Administrator has been designated as the Source Selection Official for all of these procurements except FTS where the Associate Administrator will be the selection official. Operations capability development projects are planned at JSC, MSFC, KSC, GSFC, and LeRC. Each of these centers will develop a procurement approach that best fits its other operations facilities and needs.

Because of the distributed nature of Space Station procurement activities, an extensive effort continues on the part of the SSPO to provide coordination among all NASA participants in major procurements. Where appropriate, common reference documents, common requirements, and common contractual provisions were established and used across the procurements. Each participating center was given the opportunity to review and provide comments on the RFP from each of the other centers. Finally, each RFP was formally reviewed and approved by NASA Headquarters before release to industry. Source Evaluation Board membership at each center included representation from the other participating NASA centers. A Space Station Program Procurement Coordination Committee consisting of representatives from the SSPO, all participating centers, and NASA Headquarters General Counsel and Procurement Offices was established to provide a steering mechanism to ensure consistency among procurement activities.

The PSC, TMIS, and SSE contracts, all of which will be managed by NASA Headquarters, have been awarded to major U.S. aerospace firms. Proposals for the FTS and proposals for the work package procurements received in September 1987 are currently being evaluated.

D. SAFETY AND PRODUCT ASSURANCE

Introduction

Safety is of paramount concern to NASA in the development of the Space Station. Ensuring the well-being of the Station crew is an objective that permeates nearly every aspect of its planning. Although risk cannot be eliminated from space flight, it can be understood and minimized. Ultimately, the Program will have to balance risk, cost, and benefits. A concerted effort will be made to assure that Space Station operations are safe. The Space Station Safety, Reliability, Maintainability, and Quality Assurance (SRM&QA) program has been designed to take advantage of lessons learned from past programs. The Space Station, however, has many unique characteristics and requirements which challenge the state of the art in SRM&QA management philosophies and techniques. Factors related to long life, safety, and product assurance include the following:

(a) An on-orbit equipment failure must be rapidly identified and located.
(b) The Space Station must have an across-the-board capability for restorability in the event of failures while at the same time being able to sustain a variety of normal user operations.
(c) The Space Station consists of many large, complex, and diverse elements that must be assembled and activated on orbit over a period of many space missions. The final system integration and verification activities will take place on orbit.
(d) The Space Station developmental and operational costs must be kept to reasonable levels consistent with the safety and/or reliability requirements.

Rigorous implementation of SRM&QA requirements and procedures will result in safe, reliable, long-life Space Station operations.

The Space Station Program safety and product assurance requirements are defined and controlled by the Space Station Program Requirements Document and the Space Station Program Definition and Requirements Document. The Space Station Safety and Product Assurance Program is also based on policies and requirements as set forth in the agency-level management documents. Implementation plans for Space Station safety and product assurance are defined and specified in Safety and Product Assurance Program Plans which are prepared by Levels II and III and by the Space Station contractors.

Space Station international partners will generate their own safety and product assurance requirements documents and implementation plans. These requirements and plans will be equivalent to or exceed corresponding NASA safety and product assurance requirements. NASA personnel will be permitted to participate, as necessary, in design review and technical meetings conducted by Space Station international partners. In accordance with the international agreements currently being negotiated, NASA will have the ultimate responsibility for the safety of the Space Station and will be the final authority on all issues relating to safety.

The Space Station Safety and Product Assurance Manager for Level I is a collocated assignment from the Associate Administrator for SRM&QA to the Associate Administrator for the Office of Space Station. The Level I Safety and Product Assurance Manager is responsible for advising the Space Station Associate Administrator on Program SRM&QA requirements policy and issues in an independent manner while maintaining a role as an integral member of the Space Station management organization. Safety and product assurance organizations at both Level II and Level III will also be collocated to various project offices. Level II will also have direct support for all SRM&QA functions from the Space Station PSC. Level III will ensure that the work package contractors have the appropriate SRM&QA requirements in subcontractor contracts and purchase orders and assure compliance therewith. The Level III Safety and Product Assurance Managers will utilize the Department of Defense contract administration offices for direct safety, reliability, and quality assurance support and surveillance at manufacturing locations. In all cases the product assurance and safety organizations are collocated with the Program and project offices and retain direct access to the senior Program or project manager. For all significant SRM&QA concerns, issues, and policy matters, the SRM&QA Managers have direct, unimpeded access to the senior SRM&QA institutional management.

The safety and product assurance organizations at all levels are also significantly involved in the contractor award fee processes. The Associate Administrator for SRM&QA is a member of the Award Fee Determination Board thereby ensuring that appropriate consideration for SRM&QA input receives the highest level of consideration during the award fee determination process.

The Safety and Product Assurance Offices at each level will have members on the appropriate change control boards. As a result, each change will be examined for SRM&QA implications. As board members the Safety and Product Assurance Managers will have the responsibility and authority to assure that changes will be consistent with the SRM&QA objectives.

Safety

Program safety objectives will identify and evaluate Space Station design and operational activities to assure that measures are taken to minimize risks. The system safety objectives include performing safety analyses to identify the hazards associated with hardware, software, and operations during all Program phases; assuring that proper design and performance requirements eliminating or controlling the identified hazards are developed, documented, and implemented; and performing an overall risk assessment including the identification of residual hazards and/or risks.

Safety requirements will be incorporated into system design, operations, and procurement documentation including facilities, Ground Support Equipment (GSE), and flight hardware and software. A verification system will be used to maintain current requirements documents and reference the next higher or lower requirement document, assure specific requirements are imposed, and report implementation status of requirements.

Safety analyses will be performed for the purpose of identifying the hazards associated with the hardware, software, and operational environments. The analyses will be evaluated, and the resultant actions will be considered by the CCB. The analyses shall identify hazardous conditions, causes, effect, controls, and verification methods. Operating and support hazard analyses will address events associated with the fabrication, assembly, test, checkout, launch, use, maintenance, disposal, and on-orbit operations.

The foremost consideration will be to remove hazardous sources and operations. Corrective action priorities will be established to reduce potential for personnel and material losses. Actions for satisfying safety engineering requirements will be in the following order of precedence:

(1) Hazard elimination. The hazard source or the hazardous operation will be eliminated.
(2) Design for Minimum Hazard. The major goal throughout the design phase will be to ensure inherent safety through provisions of appropriate design features, materials and parts selection, and safety factors. Damage control, containment, and isolation of potential hazards and failure tolerance considerations are to be included in design considerations.
(3) Safety Devices. Known hazards that cannot be eliminated by design will be reduced to an acceptable level by incorporating safety devices as part of the system, subsystem, or equipment.
(4) Warning Devices. Where it is not possible to preclude the existence or occurrence of a known hazard, warning devices will be employed for the timely detection of hazardous conditions and the generation of adequate warning signals.
(5) Special Procedures. Where it is not possible to reduce the magnitude of an existing or potential hazard by design or by use of safety and warning devices, special procedures will be developed to counter hazardous conditions for enhancement of ground and flight crew safety.
(6) Personnel Protective Clothing and Equipment. Protective clothing and equipment to minimize the effects of potential hazards will be provided.

Space Station safety organizations will, on a selective basis, perform (or cause to be performed) independent assessment(s) of hazard dispositions and/or residual hazards.

Other safety activity areas include the following: hazard closure criteria, human engineering, industrial safety, test operations safety, required safety certifications and approvals, and flight operations safety.

Reliability and Maintainability

The prime functions of Space Station reliability organizations will be to assure compliance with the following reliability goals: critical hardware and/or functions will be two-failure tolerant; Space Station hardware will be serviceable on orbit and restorable, on orbit, including replacement in the event of failure; conservative design margins will be established vis-a-vis performance requirements; Space Station designs will utilize best available state-of-the-art preferred parts, components, etc., to meet design objectives; and Space Station systems performance will be fully verified by a combination of test, analysis, and simulation prior to launch.

A major focus of Space Station reliability activities will center on Failure Modes and Effects Analyses (FMEA)s. Critical item controls have been established for the test and verification of requirements and contingency procedures have been developed in the event that failures should occur during operation.

Other major reliability activity areas are described in detail in the Space Station Program Definition and Requirements Document and include reliability design criteria, critical Item control, limited life control, supplier control, verification assurance, maintainability assurance, and reliability participation in design reviews and engineering control boards and panels.

Electrical, Electronic, and Electromechanical (EEE) parts will be selected on the basis of suitability for their applications and proven qualifications. Selection shall minimize the number of styles and generic types and will emphasize parts with proven technologies and inherent reliability. Approved parts for Space Station are specified in published standards and all non-standard parts will require a non-standard part approval. All selected parts will be supported by qualification at the parts level.

EEE parts will be procured from approved sources to assure that all applicable requirements are met. A consolidated procurement approach which considers cost, availability, and commonality will be a major consideration for EEE parts control and acquisition.

Over an operating life of several decades, it is an assumption that any element of the Space Station could experience a failure. The Space Station must be designed to accommodate maintenance requirement as various functional systems will be replaced due to obsolescence and technological advancement.

The capability to restore failed hardware to a fully operational state safely and efficiently is a fundamental design and operational requirement for Space Station. Accordingly, all Space Station hardware must be designed for restorability and on-orbit servicing.

The Space Station criteria for achieving of desired restorability characteristics include the following:

(1) the development of a Program maintenance concept which addresses operational availability, repair versus replacement policy, level of replacement, skill-level requirements, sparing concept (i.e., on-board vs deliverable), standardization policy and practice, testability and diagnostic principles and concepts, accessibility requirements, and crew time considerations,

(2) the definition of required maintenance and servicing characteristics and capabilities to be incorporated into the Space Station design;

(3) the identification and definition of maintenance and servicing tasks that are likely to be required over the operating life of the Space Station;

(4) the requirement for contractors to prepare maintenance and servicing plans to support the established maintenance and servicing concept;

(5) the requirement for contractors to determine optimal Orbital Replacement Unit (ORU) configurations based on analysis of performance requirements, safety considerations, reliability, cost, fault detection and diagnostic requirements, accessibility requirements, unit replacement times, and weight/volume considerations;

(6) contractors will be required to demonstrate compliance with required maintenance and servicing capabilities; and

(7) any Space Station critical hardware element or function that cannot be safely and efficiently restored on orbit is a deviation from Program requirements that must have signature approval of the Director, Space Station Program.

Quality Assurance

The prime function of quality assurance is to assure that all hardware, software, and services to be procured by the Space Station Program are defined by properly prepared specifications and drawings and that all such hardware and services comply with the specifications and drawings. Major activity areas within the Space Station quality assurance discipline include design and development controls, procurement controls; manufacturing and fabrication controls; inspection, test and verification controls; metrology and calibration controls; cleanliness and contamination controls; handling/storage/marking/labeling/packaging/shipping controls; and problem reporting, corrective action, trend analyses and recurrence control programs.

Verification requirements will be defined and specified as an integral part of Space Station hardware and software procurements. Compliance with the requirements will be checked by verification, test, simulation, analysis, and inspection.

To the extent feasible, Space Station performance and functional requirements will be verified by test. Each specific performance and/or functional requirement (including maintenance and servicing requirements) will be verified by test and submitted to the Space Station Program Director for approval.

The Space Station test program includes the traditional categories of development, qualification, acceptance, and launch processing and flight tests. Because Space Station final integration and assembly takes place on orbit new approaches to test verification will be required. Similarly, new and innovative approaches will be developed to verify the capability to perform on-orbit maintenance and servicing tasks.

Detailed plans and requirements for establishing and implementing the Space Station verification program will be contained in a Space Station Master Verification Plan and its sub-tier documents.

Lessons Learned

An ongoing component of the Space Station Safety and Product Assurance Program is a review of safety and product assurance activities from previous programs. The Associate Administrator for SRM&QA is sponsoring a study of the lessons learned that will systematically analyze the findings of the Challenger accident investigations to determine the specific applicability of "Lessons Learned" to the Space Station Program. The initial phase of this study is scheduled for completion late this year.

E. PROGRAM SCHEDULE

The Space Station Program schedule is based on the goal of attaining a First Element Launch (FEL) no later than March 31,1994 with a permanently Manned Capability achieved early in 1996. Contract Start Date (CSD) for the Phase C/D detailed design and hardware development phase is targeted for November, 1987. The top-level Space Station milestones are shown in Table II-5.

Milestones

Figures II-11A, 11B, and 11C depict a near-term schedule through the summer of CY 1988. As shown, upcoming milestones include the completion of the major Program procurements, the fiscal budget submissions, completion of international negotiations and documentation, and a number of non-prime and facility-related activities.

Within the Program plan, a Program schedule has been established for use in contractor proposals and Program planning. These milestones and a more detailed set of supporting milestones have been designated as controlled milestones. They are incorporated in the Program Definition and Requirements Document and come under the formal change control procedures of that document. The current milestone dates are as shown in Table II-6.

Intersite Delivery Schedules

Distributed development responsibilities within the Program dictate the need for clear accountability and scheduling of element and system components as they move through the integration process. The interdependence of hardware and software schedules requires careful integration. A key component of the plan is the intersite delivery schedule. For each deliverable end item, these schedules depict the assembly flight assignment, the work package or entity responsible for delivery, the launch date, and intermediate deliveries necessary to complete assembly, integration and verification. Table II-7 is representative of the intersite delivery schedules.

Table II-5. NASA Space Station Schedule Plan

Milestone	Commitment Date
WP Contract Start	November 1987
First Element Launch	March 31, 1994
Man-Tended Capability	March 31, 1995
Permanently Manned Capability	Early 1996

Figure II-11a. Space Station Program Office Working Schedule

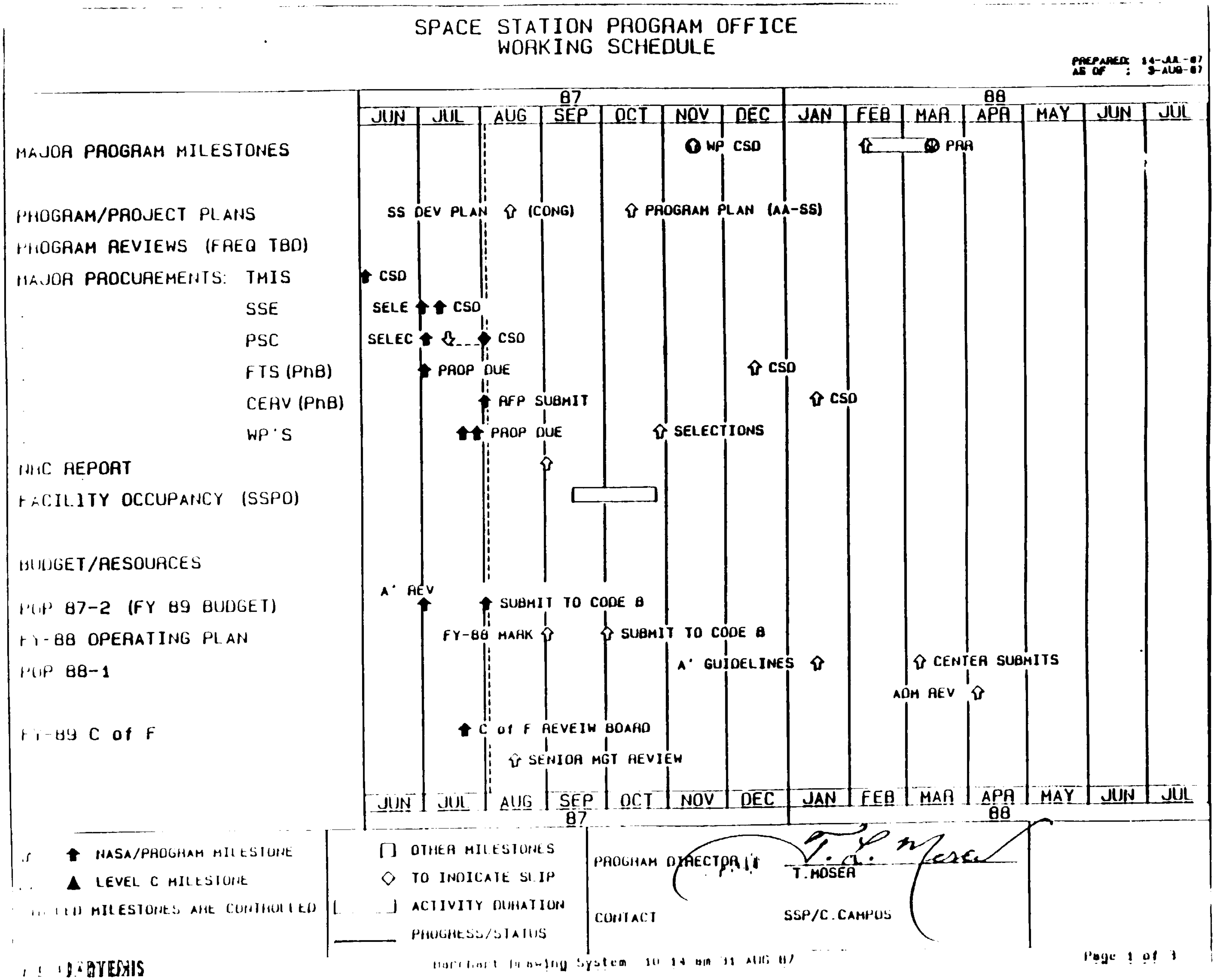

Figure II-11b. Space Station Program Office Working Schedule

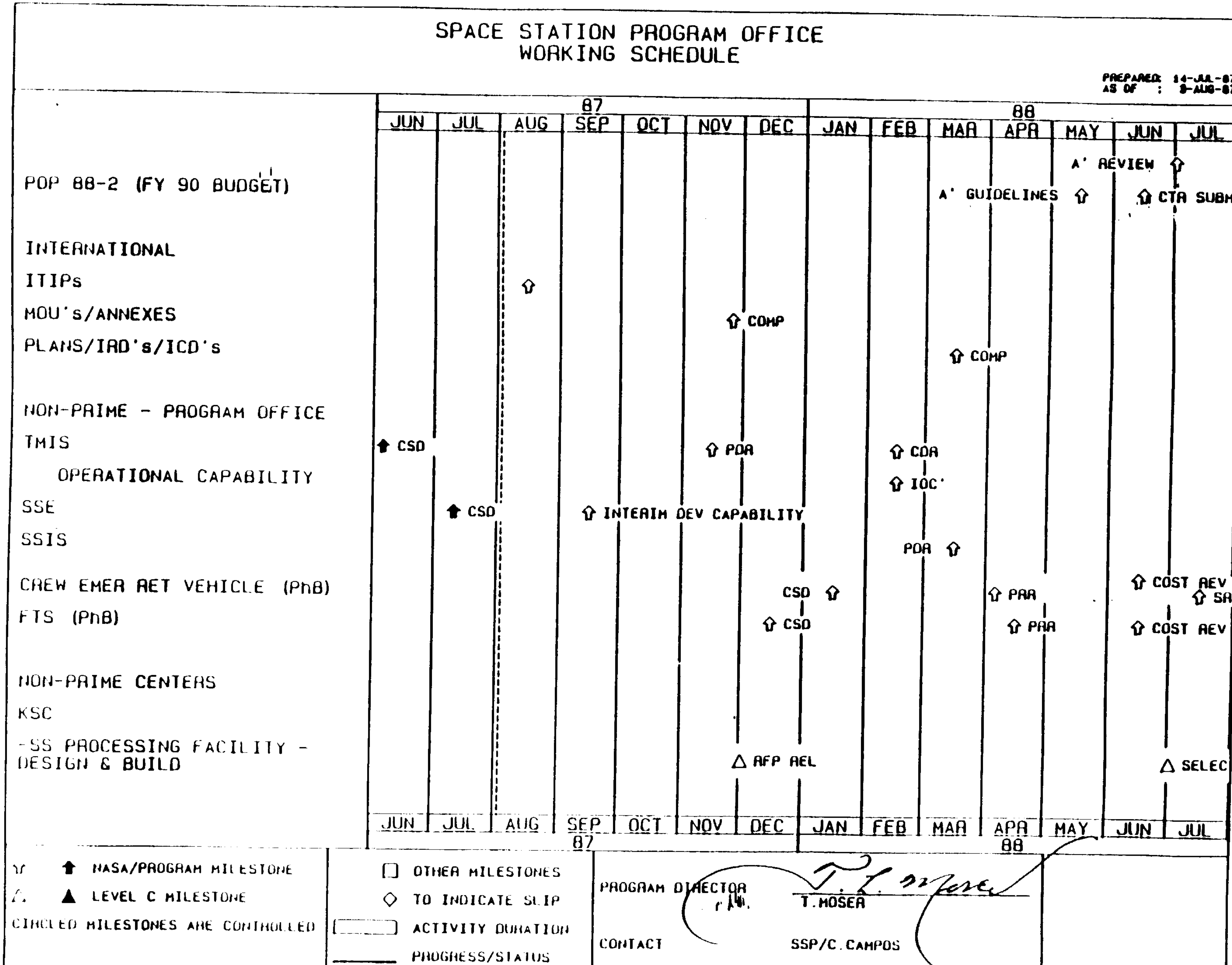

Figure II-11c. Space Station Program Office Working Schedule

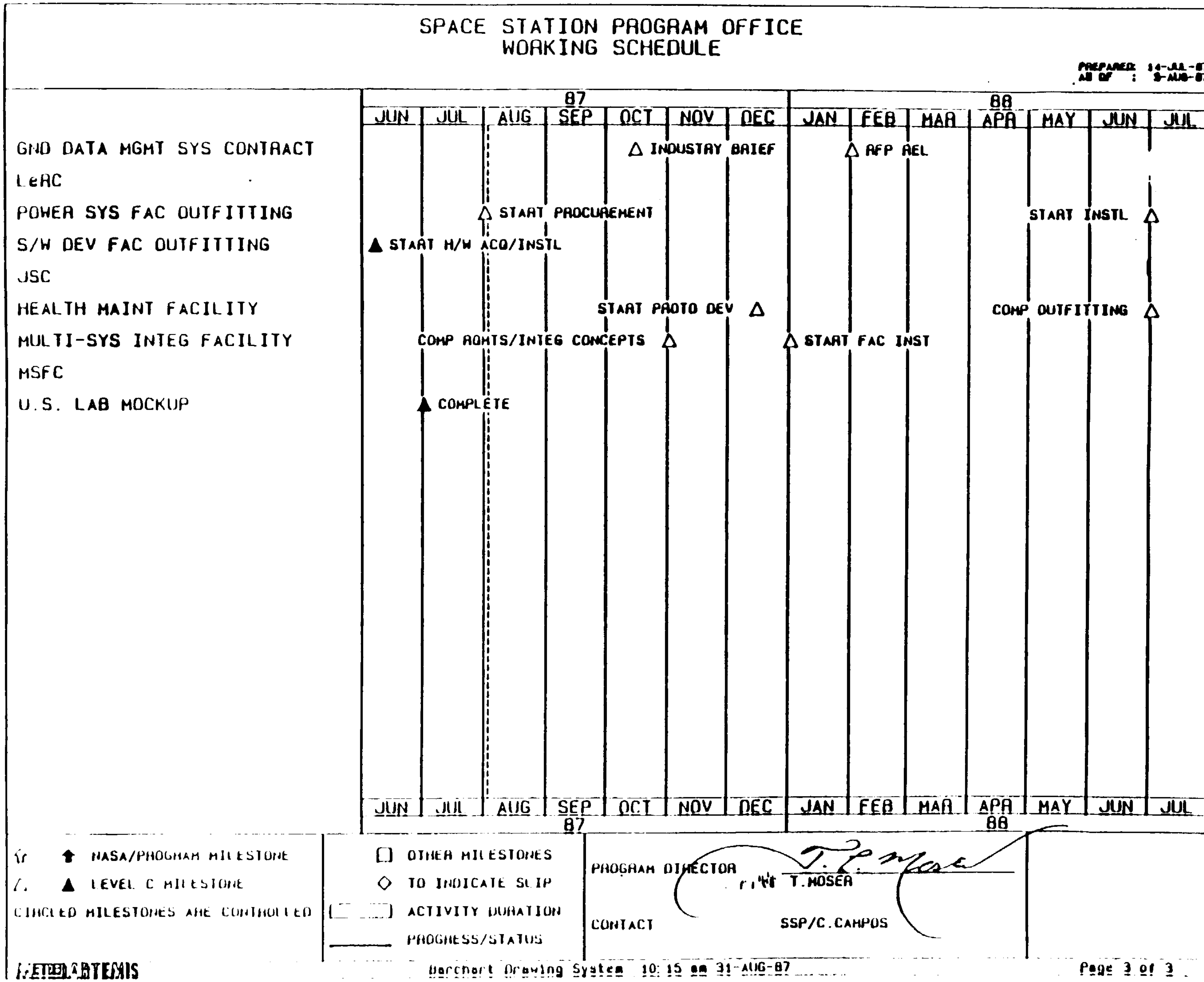

Table II-6. Space Station Milestones

Milestone (under review)	Date
Phase C/D Contract Start Date, CSD	November 1987
Preliminary Requirements Review, PRR	March 1988
Flight Systems Requirements Review	March 1988
Operations Capability Requirements Review (Initial)	May 1988
Preliminary Design Review, PDR	January 1989
Operations Capability, PDR (Initial)	January 1989
Ground Systems Requirements Review	March 1989
Operations Capability, CDR (Initial)	January 1990
Operations Capability Requirements Review (Final)	February 1990
Critical Design Review, CDR-1	August 1990
Operations Capability, PDR (Final)	January 1991
Critical Design Review, CDR-2	June 1991
Operations Capability, CDR (Final)	July 1991
Critical Design Review, CDR-3	March 1992
Operations Facility Readiness Review (Initial)	June 1992
Operations Facility Readiness Date (Initial)	July 1992
Design Certification Review, DCR-1	October 1992
Design Certification Review, DCR-2	October 1993
Design Certification Review, DCR-3	January 1995
Pre-Flight Operations Readiness Review, PORR	July 1993
First Flight Readiness Review, FFRR	October 1993
Operations Facility Readiness Review (Final)	November 1993
Operations Facility Readiness Date (Final)	December 1993
First Element Launch, FEL	March 1994
Man-Tended Capability, MTC	January 1995
Permanently Manned Capability, PMC	October 1995
U.S. Polar Platform Launch	November 1995
Assembly Complete	November 1996
Operational Readiness Review	January 1997

TABLE II-7 (SAMPLE)
(PRELIMINARY) INTERSITE DELIVERIES
WORK PACKAGE I AS OF 10 JULY 1987

END ITEM/DELIVERABLE	FLT NO.	FROM WP NO.	TO WP1	TO WP2	TO WP3	TO WP4	TO JAPAN	TO ESA	TO CAN	LAUNCH SITE O/D	LAUNCH DATE
Reso Node #1 – Structure	1	1		L-25							
Standard Racks	1	1		L-31							
ECLSS	1	1		L-25							
Internal Audio	1	1		L-27							
Internal Video	1	1		L-27							
Internal Thermal	1	1		L-25							
Common GSE	1	KSC	L-39								
Unique GSE	1	1		L-25							
Berthing Mechanism	1	1		L-25							
Hatch & Hatch Mechanism	1	1		L-24							
Manned Systems (MSSCH)	1	1		L-25							
Special Transportation System	1	KSC	L-27								
Reso Node #2 – Structure	2	1		L-24							
Standard Racks (Exc C&T)	2	1		L-30							
Standard Equipment Rack for C&T	2	1		L-34							
ECLSS	2	1		L-24							
Internal Audio	2	1		L-30							
Internal Video	2	1		L-30							
Internal Thermal	2	1		L-24							
Common GSE	2	KSC	L-32								
Unique GSE	2	1		L-24							
Berthing Mechanism	2	1		L-24							
Manned Systems (MSSCH)	2	1		L-24							
Hatch & Hatch Mechanism	2	1		L-25							
Special Transportation System	2	KSC	L-26								
Airlock (Standard) – ECLSS	3	1		L-25							

APPENDIX A
SYSTEM DESCRIPTION

This appendix describes the manned base and the platforms and discusses the on-orbit assembly sequence. This design and the assembly sequence will undergo some changes as development progresses. Also included is a brief discussion of the definition study of a Crew Emergency Return Vehicle (CERV) although it is currently not part of the Program.

Design of the Space Station has been driven to a large extent by analysis of user requirements. Payload accommodation assessments have been conducted for all payload disciplines including the potential categories of large space structures and future Program support. Assessments of materials-processing and life-science microgravity payloads have played a major role in the configuration of the Space Station and location of the laboratory modules. By designing a mass balanced configuration, it will be possible to achieve a microgravity environment.

Astrophysics and Earth observation payloads require mounting locations with unobstructed fields of view. Open areas of the transverse boom will provide sufficient space to support servicing and assembly of attached payloads and free flyers. The expansion of the truss size, from 3 to 5 meters, provides a substantial increase in optimum pointing payload locations.

During the definition phase, the length of the U. S. laboratory was increased to better accommodate payload volume requirements. The current module can accommodate up to 42 cubic meters (30 double racks) of payloads and payload support equipment. The atmospheric pressure in the laboratories and habitation module was fixed at 14.7 psi (sea-level pressure) in response to user requests to avoid the necessity for expensive reestablishment of ground-based experiment data.

Data system parameters have been sized to meet initial payload requirements and provide room for growth. The driver for Space Station payload data transmission is the transfer storage, and downlink of digital television from externally mounted payloads (22 to 44 Mbps). Instruments for the polar platform may require up to 300 Mbps of data transmission. The power capability of the Station has been sized to support multiple high power (7 to 20 kw) payloads, in particular materials processing furnaces, other materials processing facilities, and plasma physics payloads.

The number of crewmembers which the Station is designed to support is directly related to both the size of the modules and the anticipated workload. This crew support capability will be complemented by extensive payload automation support and the use of artificial intelligence. Support for the use of robotics in payload installation, resupply, and repair outside the modules will be provided. Internal robotic elements will be supported by the Data Management System (DMS). Figure A-1 depicts the configuration and identifies the responsibilities of the NASA field centers and the potential international partners for elements and systems. The design features a 110-meter-long horizontal boom in the middle of which are attached three pressurized laboratories and a habitation module. Photovoltaic arrays generating a total average power of 75 kw are located at the ends of the boom. Two attachment points for external payloads are provided along this boom. There will be a telerobotic servicer and

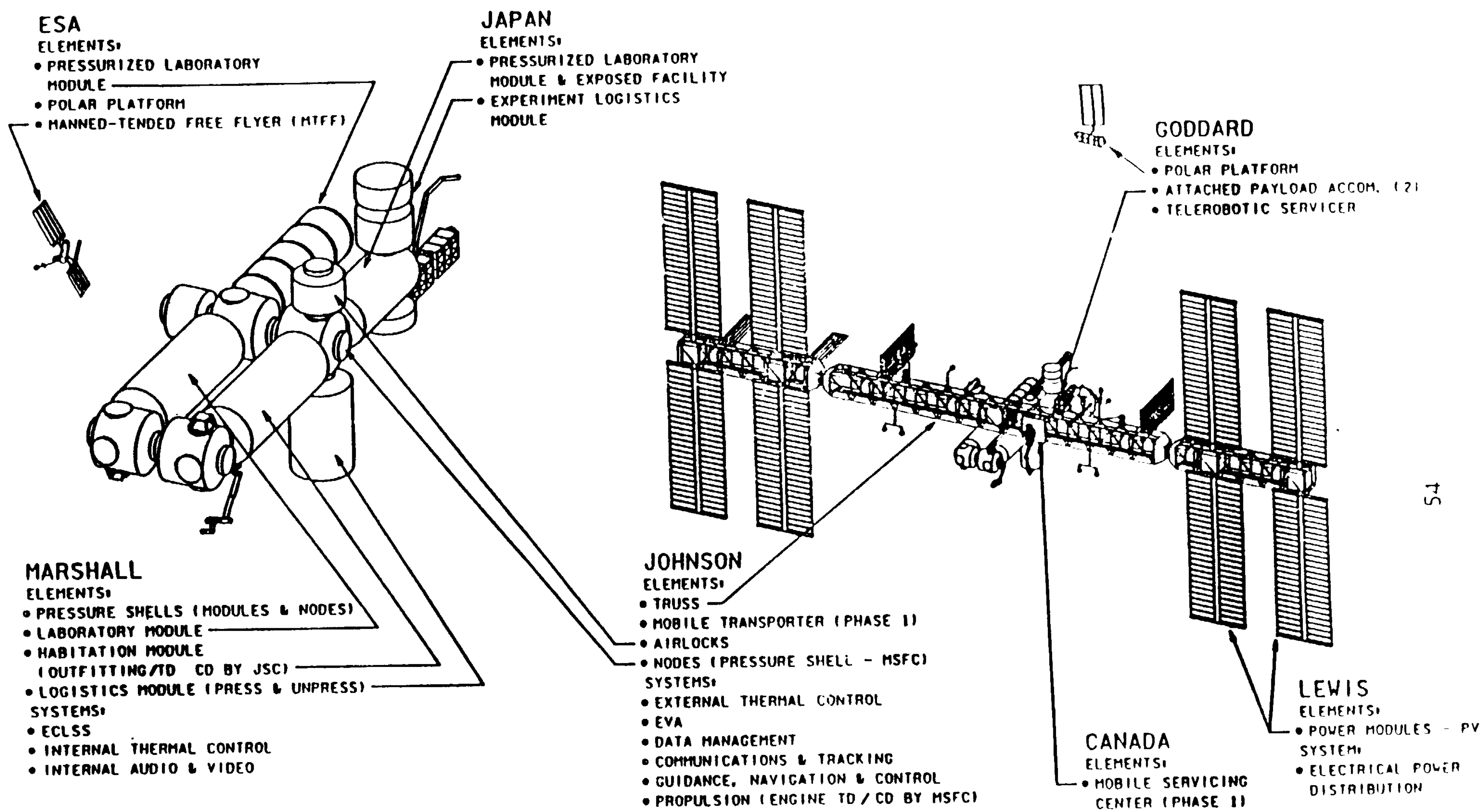

Figure A-1. Space Station Plan

the initial phase of a mobile servicing system. The configuration will evolve to accommodate future changes in user requirements. The configuration also includes two unmanned, free-flying Space Station platforms in polar orbit. One will be developed by the United States, the other by ESA. These platforms are an integral part of the Space Station Program and contribute significantly to its versatility and utility.

THE MANNED BASE

The manned base configuration comprises the following components:

- U.S. Laboratory Module
- Columbus Laboratory Module
- Japanese Experiment Module (JEM) Laboratory and Exposed Facility
- Habitation Module
- Mobile Servicing System (MSS)
- Attached Payload Accommodations Equipment (APAE)
- Pressurized Logistics Carrier (PLC)
- Unpressurized Logistics Carrier (ULC)
- Airlock
- Hyperbaric Airlock
- Flight Telerobotic Servicer (FTS)
- Power Modules
- Truss Assembly
- Propulsion Assembly
- Resource Nodes
- Distributed Systems

A description of the manned base components follows.

U.S. Laboratory Module

The U.S. laboratory module is a pressurized cylinder, approximately 45 feet in length and 14 feet in diameter, that will support multi-discipline payloads within a habitable volume. The U.S. laboratory module will be developed to utilize the basic structural design and distributed systems needed to function within all the modules. Principal activities such as basic materials and life science research will be conducted inside the laboratory where low-acceleration levels of long duration, control, and monitoring of experiments and associated apparatus are required. See Figure A-2. The commercial potential of material processes in a very low gravity environment will be investigated in the U.S. laboratory module.

The primary structure consists of the pressure shell, meteoroid shield, NSTS attachment provisions, Space Station attachment provisions, viewports, and grapple fixtures. The secondary structure provides rigidity for attaching equipment to the interior of the module and functional units and racks for support of subsystems and equipment. Standard interface guidelines and resources are provided for both the Space Station and the user. Laboratory operations are managed and controlled in an element control workstation located in the U.S. laboratory module. The U.S. laboratory module also contains provisions for telescience to allow interaction between ground based experimenters and on-orbit experiments.

Functional outfitting equipment will be provided to support on-orbit research and experimental operations. Outfitting equipment will include facilities and apparatus for (1) decontaminating a crewmember should an accident occur involving a toxic substance; (2) monitoring the microgravity environment; (3) preparing and packaging pre-and post-processed samples and specimens; (4) monitoring common fluids and gases routinely required in laboratory operations; (5) handling and storing safely experiment wastes; (6) assaying and characterizing processed samples and specimens; and (7) supporting minor adjustment and repair of equipment.

As depicted in the Figure A-2, user-provided payloads and laboratory support equipment involved in day-to-day operations are located along the port and starboard walls of the U.S. laboratory module. Core subsystems, such as Environmental Control and Life

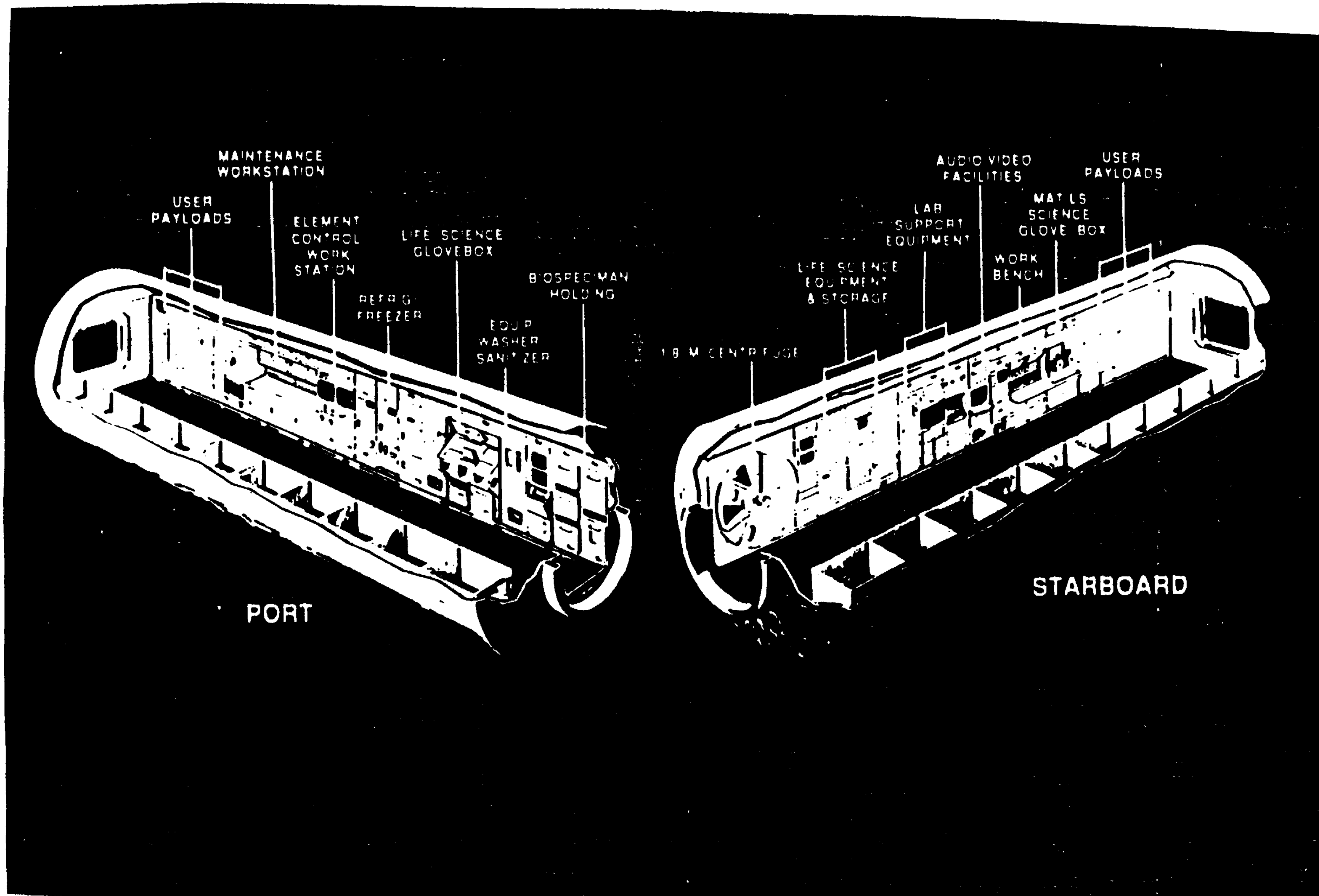

Figure A-2. U.S. Lab Module

Support Systems (ECLSS), outfitting equipment, storage lockers, and equipment requiring infrequent access, are located in the ceiling and floor.

Columbus Laboratory Module

The Columbus laboratory module is a permanently attached, pressurized laboratory module to be built by ESA. The Columbus module is composed of four segments of all-welded primary structure with axially mounted Station-compatible docking ports at each end cone. The internal secondary structure includes removable single and double racks for accommodation of subsystems and payloads. The total volume available for payloads and storage will support approximately 40 single racks. A scientific airlock permits temporary exposure of experiments to vacuum and is also used for the transfer of tools and equipment to support external activities. See Figure A-3.

Japanese Experiment Module (JEM) Laboratory and Exposed Facility

Japan is planning to provide a permanently attached, pressurized laboratory module, an exposed facility, and an Experiment Logistics Module (ELM). See Figure A-4. The exposed facility will be used for scientific observations, Earth observation, communication, and advanced technology development and materials processing for which the unpressurized exposed facility is preferred or required.

The pressurized module structure consists of a cylindrical pressure shell with end-cones, a meteoroid bumper, windows, grapple fixtures, and secondary structure. The module is outfitted with subsystems including electrical power, thermal control, communications, Environmental Control and Life Support (ECLS) and experiment support. The exposed facility consists of an open truss and equipment-attach provisions. The airlock provides access between the pressurized module and the exposed facility and consists of a pressure shell, hatches, a slide table, and controls for pressurization and depressurization.

The ELM provides transportation and storage of logistics items and has the potential to serve as a safe haven for two crewmembers. Consisting of pressurized, exposed, and gas container sections, the ELM will be transported in the NSTS Orbiter payload bay to the Space Station. Following Orbiter docking, the MSS will remove the ELM from the Orbiter payload bay and mate it with the JEM pressurized module.

Habitation Module

The habitation module is an environmentally protected enclosure intended for long-duration crew activity and habitation functions (e.g. eating, sleeping, recreation, relaxation, medical procedures and work activities). The habitation module contains all of the systems necessary for providing a productive environment. Also provided in the habitation module are safe haven emergency supplies for the crew, isolation from other modules, and stowage, equipment, and supplies for daily operations.

The habitation module primary structure is common hardware and provides environmental enclosure, meteoroid protection, viewports, and accommodations for interfaces with NSTS and external elements. The primary structure consists of the pressure shell, meteoroid shield, radiation protection, NSTS attachment provisions, Space Station attachment provisions, viewports, and grapple fixtures. The habitation module secondary structure provides rigidity for attaching equipment to the interior of the module plus interchangeable functional units and racks

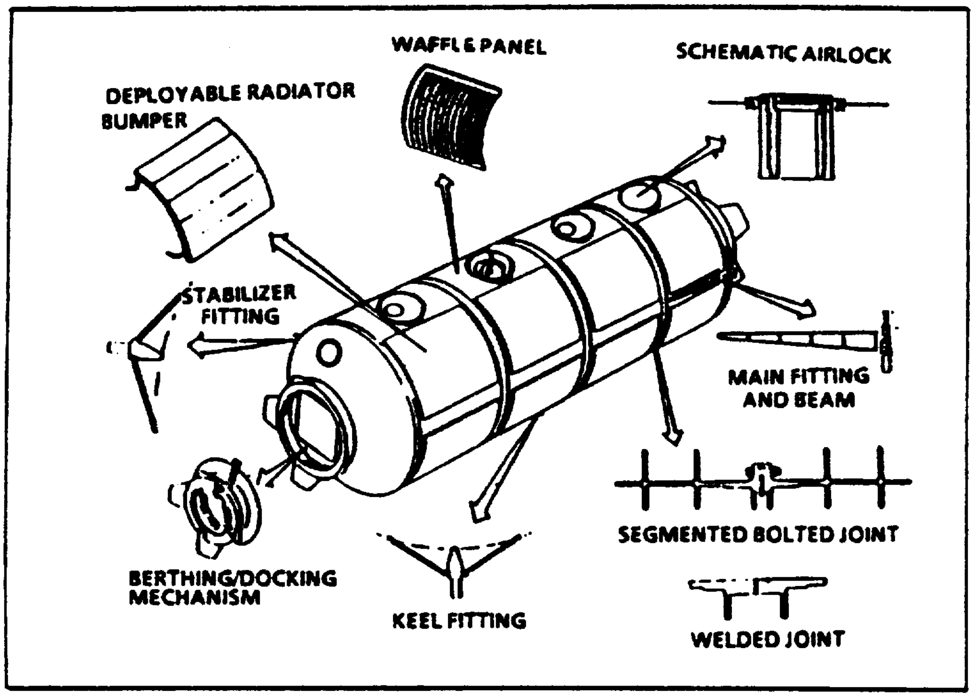

Figure A-3. External Arrangement Columbus Laboratory Module

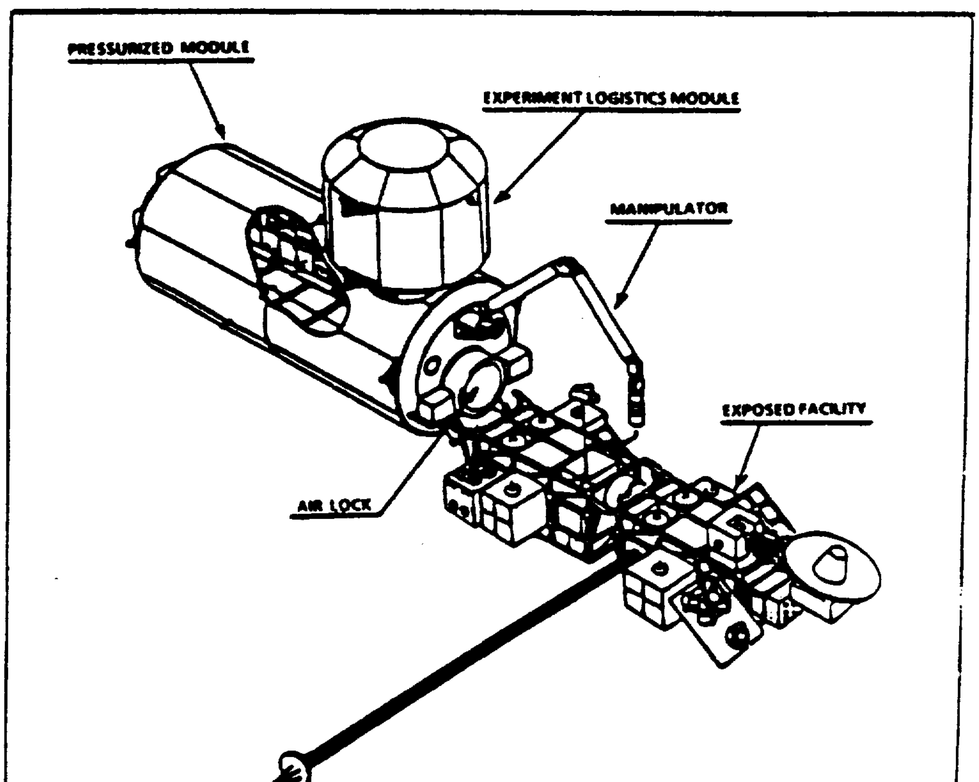

Figure A-4. General Arrangement - - Japanese Experiment Module (JEM) for support of subsystems and equipment.

Stowage provisions will be included for habitation module subsystem spares and consumables, allocated Space Station spares and consumables, Orbital Support Equipment (OSE), and subsystem maintenance and trouble shooting equipment. Stowage provisions will also be included for spares, consumables, and tools necessary for functional outfitting.

Mobile Servicing System (MSS)

The Mobile Remote Servicer (MRS), planned by Canada, and the U.S.-provided mobile transporter will make up the Mobile Servicing Centre (MSC). The MSC will be the primary element of the first phase of the Mobile Servicing System. See Figure A-5. In support of construction and assembly functions, the MSS will remove cargo from the Orbiter cargo bay, transport it to the point of construction or assembly, support EVA construction functions with flight crew positioning devices, and provide post-assembly inspection. The MSS will also transport Station elements and payloads to locations on the Space Station as well as provide deployment and retrieval functions. It will also support attached payload servicing (external), Space Station maintenance (external), EVA operations, and safe haven support.

The MSC base provides the primary structural and mechanical system for support and attachment of MSC systems and equipment. The Space Station Remote Manipulator System (RMS) provides the MSC with manipulative, positioning, and handling capability and with the attachment of standard and special end-effectors, can accomplish various tasks including providing utilities to payloads and elements.

The Astronaut Positioning Mechanism (APM) provides crew mobility and is nearly identical to the Space Station RMS. The Special Purpose Dextrous Manipulator (SPDM) is a robotic manipulator which could be used for ORU changeout of Space Station elements and attached payloads and supports other maintenance and servicing functions.

Attached Payload Accommodations Equipment (APAE)

The APAE will provide the accommodations for science, technology, and commercial user payloads external to the pressurized volume of the core Space Station and is attached to the Space Station truss structure. Accommodations will be made for installation and checkout on the Space Station, normal operations, servicing, repair, and removal. For some payloads the APAE can be used during transportation to orbit and return to the ground. The APAE will be modular, allowing various configurations to meet mission needs. This will include carriers designed to accommodate single instruments and those designed to accommodate several small instruments. Pre-integrated instrument pallets as well as instruments requiring gimballed pointing will be accommodated.

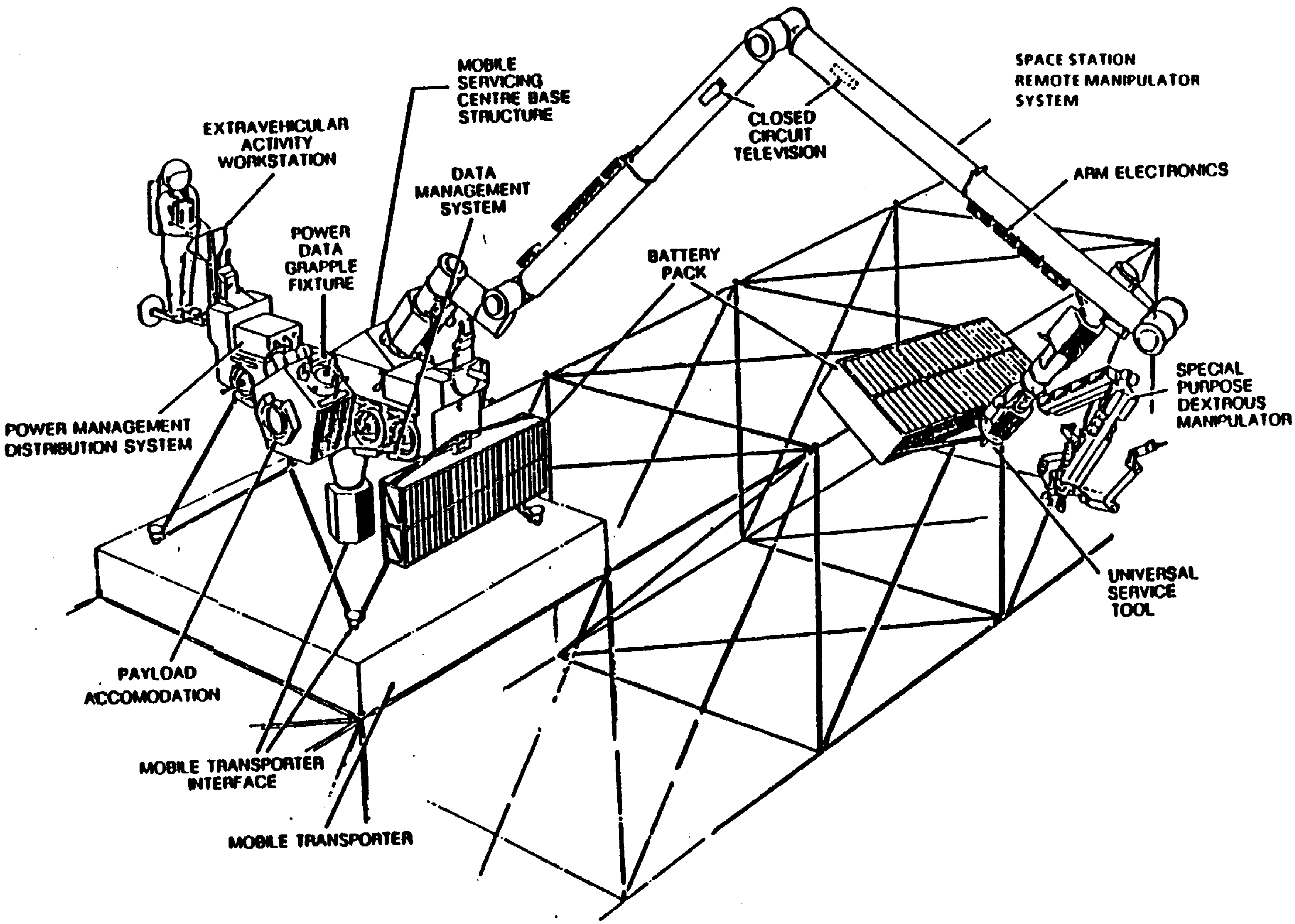

Figure A-5. Mobile Servicing Center

Pressurized Logistics Carrier (PLC)

The PLC transports equipment and fluids between the ground and the Space Station and will be carried in the Orbiter payload bay.

The PLC uses structures common to other Station modules as shown in Figure A-6. The primary structure consists of a cylindrical pressure shell with conical ends and provides a meteoroid shield, NSTS attachments, and Space Station attachments. The secondary structure provides support for the distributed subsystems and utilities; secured stowage; and containment facilities for interchangeable racks containing spare parts, ORUs, experiment parts, consumables, and other storable items.

Unpressurized Logistics Carrier (ULC)

The ULC transports equipment and fluids to the Space Station and returns items to the ground. The cargo transported does not require a pressurized environment and is used external to the pressurized volume. The types of cargo accommodated by the ULC include ORUs for the Space Station, station payloads and experiments, and fluids.

The ULC cylindrical structure provides support for racks, tanks, and subpallets; grapple fixtures and NSTS attachment fittings; and hard points for non-rack mounted hardware and subsystem equipment. See Figure A-7.

Airlock

The airlock provides the capability to transfer EVA-suited crewmembers and equipment between the pressurized and unpressurized areas of the Space Station. Storage and servicing of EVA system equipment is also provided by the airlock.

The distributed systems and utilities required to support a manned environment are an integral part of the airlock. The airlock structure provides the functions of a pressure vessel, radiation and meteoroid and debris protection, hatches, and support for the installed equipment. Openings for egress and ingress and the capability to move small items between pressurized and unpressurized areas without depressurizing the entire airlock are provided.

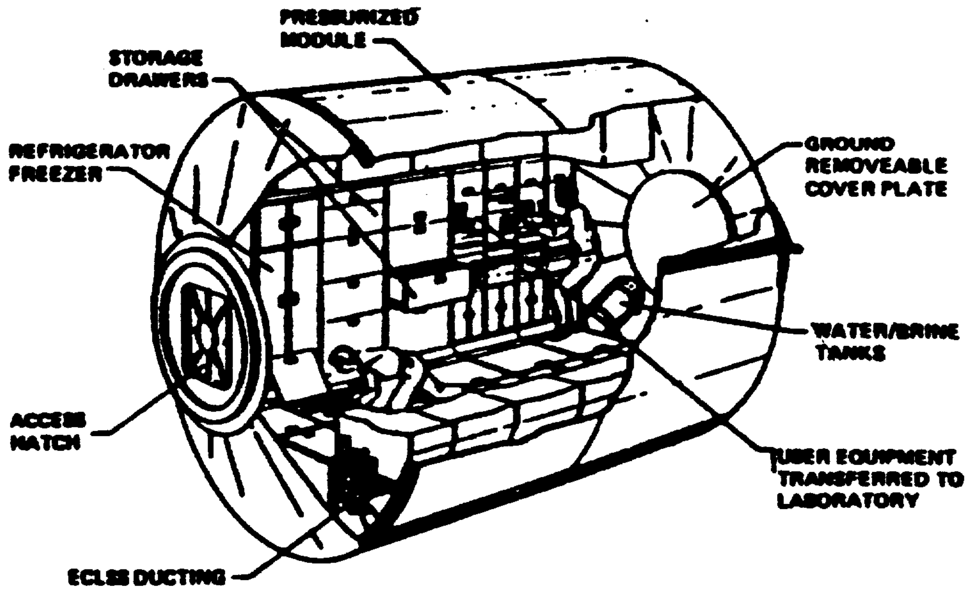

Figure A-6. Pressurized Logistics Carrier

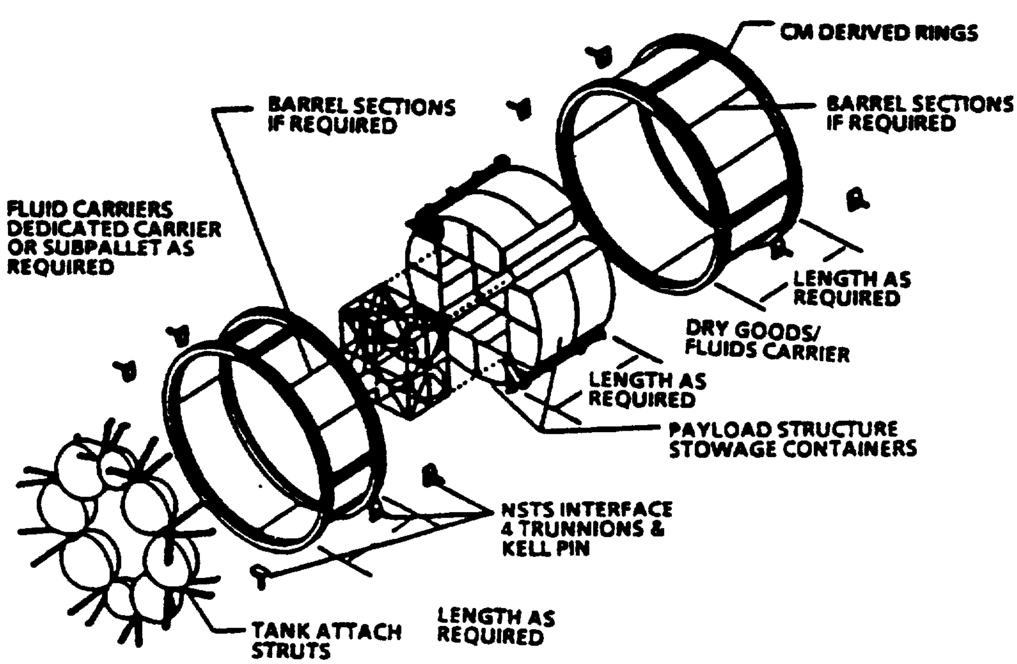

Figure A-7. Unpressurized Logistics Carrier

Hyperbaric Airlock

The hyperbaric airlock is capable of functioning at higher pressures in the event that a crewmember requires medical attention. The hyperbaric airlock has the capability to pass items to and from the Space Station without losing pressure during hyperbaric operations. See Figure A-8.

Flight Telerobotic Servicer (FTS)

The FTS onboard the Space Station increases crew safety and productivity by reducing EVA time, using robotics for hazardous tasks, and freeing crew-members from routine tasks. In the development of A&R technologies, the FTS will play a key role.

Proposed initial capabilities of the FTS include installation and removal of truss members, installation of fixtures on the truss, changeout of Space Station ORUs, mating the Space Station thermal utility connectors, and performing inspection tasks.

The FTS will be operable by using both direct manipulator control and command sequences. The FTS must be operable from different workstations as the Space Station develops. At the Space Station FEL, it must be operated from the NSTS. Later it must be able to be controlled from inside the Space Station.

The FTS element has been divided into eight separate subsystems each having unique functions. The Structures and Mechanisms subsystem provides hardware and software interfaces for attaching the FTS to a transport device, worksite, or storage area as well as for being grappled and for power and data connections. The telerobot structure provides strength, and houses the components and accommodations for other subsystems. The Telerobot Control Subsystem provides control of the robot and its manipulators during all mission operations. The Telerobot Safing Subsystem provides for safe and orderly telerobot operation and shutdown upon failure detection. The Workstation Subsystem provides the man-machine interfaces for both tele-operation and autonomous control of FTS operations by an operator. It includes all the FTS unique hardware and software necessary for sensor processing and robot control. Other subsystems provide power, thermal control, communications, and data management.

The modular structure of the FTS hardware and software will ensure serviceability. Its flexible configuration will facilitate evolutionary and technological upgrades to the Space Station.

Power Modules

Each power module is capable of collecting solar energy and converting it to electrical energy. Power modules can also store energy for orbital operations, transfer electrical power to Station power-using elements, and control the operation of the Electric Power System (EPS) equipment housed in the power module. The total average power will be 75 kW.

A general representation of a photovoltaic power module is shown in Figure A-9. The primary structural component will be struts similar to those which make up the truss element. Secondary structure will be provided to support and attach system and element-supplied equipment. Primary and secondary structures will be used to derive node spacing identical to the main truss. Power distribution and control equipment will be provided to allow powering and control of individual loads within the element.

Truss Assembly

The truss assembly provides the structure for integration and installation of

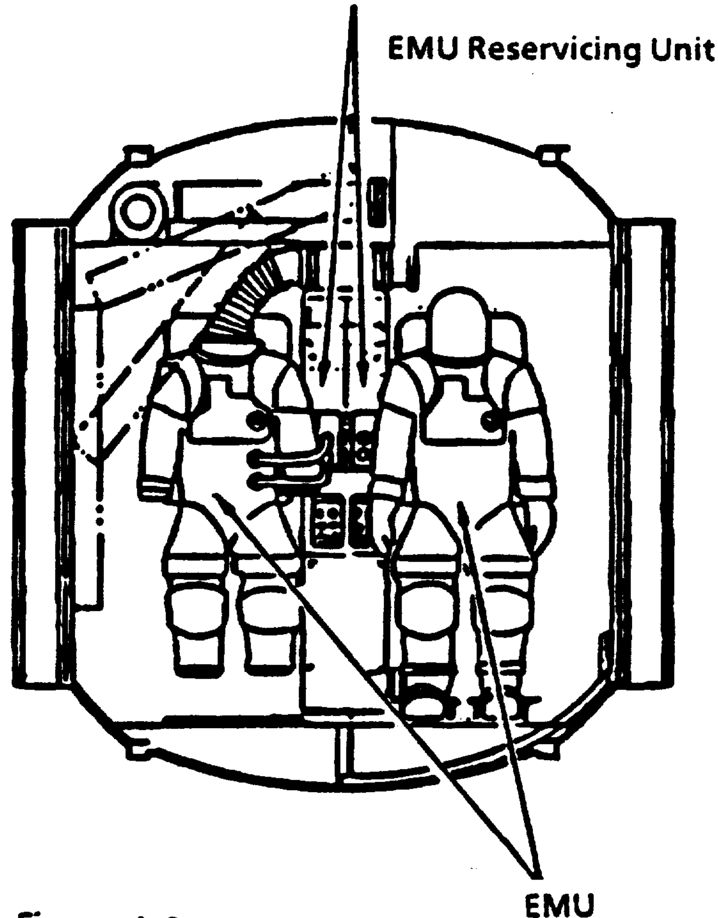

Figure A-8. Hyperbaric Airlock

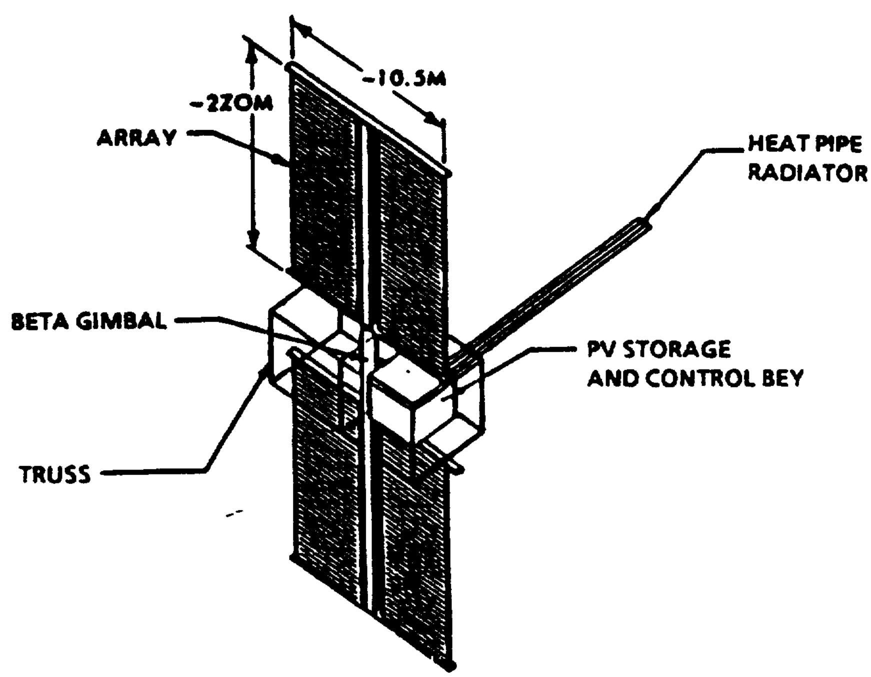

Figure A-9. Photovoltaic Power Module

the distributed systems and elements. The truss element includes the core Station integrated truss structure, all distributed systems and element-supplied equipment within the truss structure, and provisions for mounting and attaching other elements. The truss also provides corridors for crew and equipment movement, utility distribution networks, and solar array pointing capability with the alpha joint and drive mechanism.

The truss structure is an in-space erectable structure composed of longerons, battens, and diagonal struts. These members are attached to corner fittings forming a beam truss of sequential cubic bays measuring 5 meters from strut centerline to centerline. The truss provides structural stiffness and dimensional stability for the Station. Fittings also provide attachments for mobile interfaces.

EVA truss equipment is provided to assist a crewmember when moving about the structure. Unpressurized logistics carriers pallets are interfaces for attaching the logistics carriers to the truss. Resource pallets are common interfacing hardware for attaching external Station systems to the truss and utility distribution system.

All subsystem distribution lines (thermal, power, fluids, and data management) are housed in the utility distribution trays. These trays facilitate on-orbit assembly of the utility distribution system and provide protection from natural and induced environments. External lighting provides visual monitoring of rendezvous and other external activities.

Propulsion Assembly

The propulsion assembly provides three-axis thrust for attitude stabilization and reorientation control should disturbances exceed the primary momentum system capability. The assembly provides thrust to compensate for atmospheric drag and to execute collision avoidance, and it contains propellant reserve.

Propulsive thrust is achieved from two sources. The recombination of oxygen and hydrogen extracted from onboard water by electrolysis provides the primary attitude control thrust. Waste products are used as fuel for low-thrust resistojets to maintain altitude.

Resource Nodes

The resource node is a pressurized and environmentally protected enclosure intended for crew activity such as Space Station command, control, and operation. Distributed systems and related controls are housed in the nodes and provide module pattern growth. Each node will be outfitted for specialized functions. See Figure A-10.

Node 1 is the unmanned spacecraft control center. Node 1 provides a pressurized passageway to and from the modules, hyperbaric airlock, and logistics elements and provides berthing for the hyperbaric airlock, pressurized modules, and logistic module. This node provides Space Station control of unmanned flights as well as man-tended operations. Node 1 contains major components of the propulsion subsystem and has direct interface with the Columbus laboratory module provided by ESA.

Node 2 is the man-tended command and control station. Node 2 provides a pressurized passageway to and from the modules, airlock, and logistics elements and provides berthing for the airlock and pressurized modules. Node 2 contains the airlock control station and has direct interface with the Japanese Experiment Module (JEM) laboratory.

Node 3 is the primary command and control station for the Permanently Manned Configuration (PMC). It provides a pressurized passageway to and from the modules and NSTS, berthing for the NSTS, and attachment capability for the cupola. This node provides the Space Station primary command and control workstations and contains distributed systems of the Space Station utility systems, mechanisms for the module-to-node berthing and module pattern growth, a proximity operations control station, pressurized attached payload accommodations equipment port, and a backup Mobile Servicing System (MSS) control station.

Node 4 is the proximity operations station, prime MSS control station, and reserve volume. It provides a pressurized passageway to and from the modules and the NSTS, berthing for the NSTS, attachment capability for the cupola and pressurized modules, and module pattern growth. This node provides the Space Station prime MSS command and control workstations and contains utility systems, mechanisms for the module-to-node berthing and module pattern growth, and cupolas for the proximity operations control station.

The node primary structure provides the pressurized shell including the frame and skin. The secondary structure provides interfaces for external environmental protection, rigidity for attaching equipment and utilities to the interior of the module, and attachment points for hardware. The function of berthing and attaching elements to the node, truss and cupola, the cupola interface, and the pressurized payload accommodation interface, docking equipment, and hatches is also provided by the secondary node structure. Cupolas are attached to node ports to allow direct viewing of external activities.

DISTRIBUTED SYSTEMS

There are a number of subsystems that provide services and capabilities that are located in more than one module or element and have to transit the boundaries and interfaces between modules and elements. These distributed systems provide essential functions and are listed below.

- Electric Power System (EPS)
- Data Management Systems (DMS)
- Thermal Control System (TCS)
- Communications and Tracking (C&T) System
- Guidance, Navigation and Control (GN&C) System
- Extravehicular Activity (EVA) System
- Environmental Control and Life Support System (ECLSS)
- Man Systems
- Fluid Management System (FMS)

A description of the Space Station distributed systems follows.

Electric Power System (EPS)

The end-to-end EPS architecture for the Space Station begins with the collection of solar energy and extends to every place that electric power is consumed. The EPS includes load converters required to convert the distributed power to a different type for specific local use and components beyond those converters which are required to distribute power to the location of its use.

The EPS configuration consists of two photovoltaic modules on both sides with each module having two solar array wings. The continuous average power level capability of the EPS at this phase of the Program is 75 kW.

Power generation, energy storage, system control, and some distribution equipment are located in the photovoltaic modules.

The power generation equipment includes source power converters to convert the output of the basic generation system to the utility grade 20 kHz, single phase, alternating current power which is distributed throughout the Space Station. The outputs of these converters are synchronized and locked to a common frequency to allow paralleling. Energy storage is accomplished by means of nickel hydrogen batteries. Appropriate power system controls are included in each of the modules to regulate the generation, storage, and converter functions.

The overall distribution subsystem includes all equipment necessary to process, control, and distribute power from source to load interfaces. These interfaces include housekeeping loads for the overall Station operation, attached payloads, and module payloads.

The electrical primary distribution architecture for the Station manned core is implemented as a modified dual-ring bus system which provides utility power to external load areas. Each of the four modules will be supplied through one or more nodes. Transformers are used at the node penetrations to provide isolation for the single point ground system and to reduce voltage to the standard value supplied. See Figure A-11.

Data Management System (DMS)

The DMS is an ensemble of common hardware and software including a family of standard processors, network devices, mass memory storage units, and a time and frequency distribution system. The DMS also controls and monitors media for crew and experimenters. These common resources are utilized by all Space Station systems to satisfy their respective data and information management responsibilities.

The common DMS resources are configured to provide and support semi-autonomous operations of distributed systems and payloads. The DMS utilizes internationally agreed standards for Open Systems Interconnect for inter-processor network communications. The network, in conjunction with standard user interfaces, permits remote and distributed control and monitoring of Space Station activity. DMS software services include user functions such as onboard data base management operations, fault and redundancy management, vehicle and systems configuration management, and services for vehicle operations such as systems initialization, caution, and warning. In addition, DMS architecture for an automated Operations Management System (OMS) encompasses onboard applications software for crew activities planning, command and resources management, and onboard integration and verification testing.

Thermal Control System (TCS)

The TCS for the core station essentially consists of a central Active Thermal Control System (ATCS) which collects, transports, and rejects waste heat for all parts of the Space Station. The heat is collected from Space Station systems or payloads through a heat exchanger to a thermal bus. There are two thermal buses interconnected by a heat exchanger. The external bus uses ammonia, and the internal bus uses water as working fluids. Heat is transferred by the thermal bus to radiators where heat is rejected.

Surface coatings and thermal blankets are used to provide thermal protection and heat balance between sensitive components and the environment. Electric heaters or waste heat is to be used for precise temperature control of critical items.

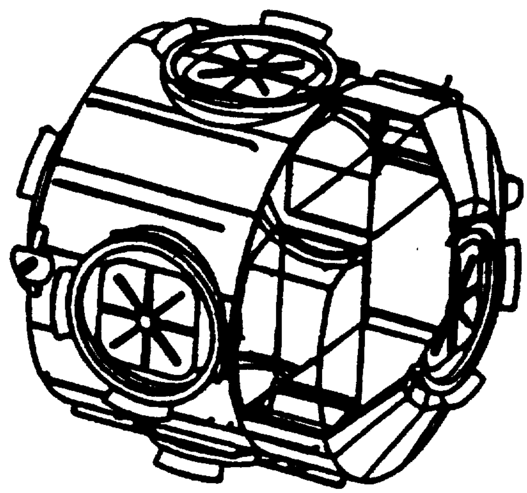

Figure A-10. Resource Node

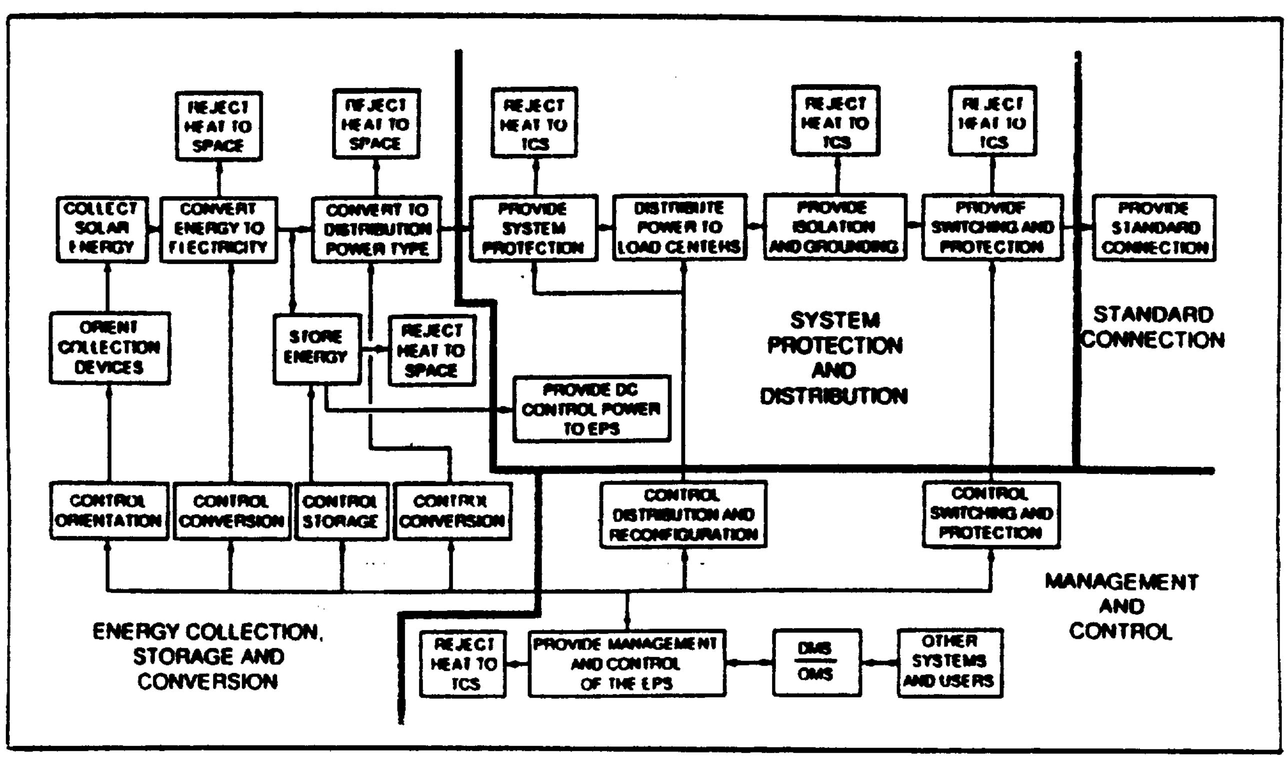

Figure A-11. Electrical Power System

Monitoring, control, data acquisition, and Caution and Warning (C&W) functions interface with the DMS. See Figure A-12.

Communications and Tracking (C&T) System

The C&T System provides all required communications services for the Space Station within and between pressurized elements, between the manned Station and all external space elements, and between the Station and ground based elements. These services include necessary Radio Frequency (RF) data transmissions; video generation, processing, distribution, and control; audio generation, processing, distribution, and control; and all communication services required by the Guidance, Navigation, and Control (GN&C) System. Also included in the system are the necessary interfaces to the DMS and the components required to furnish the built-in management, administration, and operation of the elements of the system.

Development responsibility for the system has been partitioned into two components: the hardware and communication functions necessary for external operations (EVA, outside monitoring, navigation, Shuttle docking, etc.) and those functions necessary for all internal communications. Responsibility for the external component is assigned to JSC to provide a close interface with the assembly and EVA tasks while development for the internal component is assigned to MSFC since this component is an integral part of the development and functional performance of the module systems.

When full operations are achieved, space-to-ground communications will be via a digital format radio system which communicates to ground stations through the TDRSS using a steerable, parabolic antenna. S-Band equipment will provide an initial Space Station - to - ground communications capability through TDRSS at low data rates and will thereafter be available for use as a contingency link.

Primary space-to-space communications will be accomplished through a multi-access system which will be capable of simultaneous two-way communications to support EVA operations and communications to other space vehicles which have compatible systems. These links will be capable of carrying voice, video, and data which can then be distributed, as appropriate, to other Space Station subsystems upon reception. In addition, the C&T system will receive timing signals from the Global Positioning System (GPS) constellation and generate the Space Station orbital data for navigation requirements. The GPS data will also be utilized to generate the Station timing reference.

The internal video subsystem will provide a comprehensive closed-circuit television capability within the Space Station along with a full range of media-standard processing capabilities. These video processing capabilities include video storage, retrieval, compression, special effects, graphics, and digital processing (where appropriate). The subsystem will allow special area monitoring, will support conferencing between crew locations and between the crew and ground, and will accommodate high resolution cameras where required. The system will provide its own built-in control for test and reconfiguration as commanded.

The internal audio subsystem will be similar to a standard telephone system with private and/or conferencing capability between the internal crew, EVA crew, the crew of other manned vehicles, and compatible ground systems. The system will provide all standard ancillary audio services such as recording, playback, voice recognition, voice synthesis, message routing, built-in test, and commanded reconfiguration. In addition, this system will provide the capability to annunciate C&W to the crew, as appropriate.

Guidance, Navigation and Control (GN&C) System

GN&C provides core system control and traffic management functions. The core system provides attitude and orbital maintenance, supports the pointing of power system and thermal radiators, accomplishes periodic reboost maneuvers, and provides Station state and attitude information to other systems and users. The core GN&C will provide drive electronics at solar array alpha joints and thermal radiators.

Traffic management provides for controlling incoming, outgoing, and station-keeping traffic within the Command and Control Zone (CCZ) of the Station; controlling docking and berthing operations; monitoring trajectories of vehicles and objects that may intersect the orbit of the Station; predicting potential collisions; and supporting flight planning.

The core GN&C system consists of inertial sensor assemblies, star trackers, and control moment gyros located on the attitude control assembly of the transverse boom and standard data processors located in resource nodes 1 and 2. The GN&C System will interface directly with the propulsion system thrusters for reboost and backup attitude control. Orbital state data are provided by the GPS via an interface with the C&T System. This configuration provides a GN&C capability throughout the assembly sequence.

Extravehicular Activity (EVA) System

The EVA System provides the functions necessary for Space Station crewmembers to perform routine tasks in the unpressurized environment on and about the Space Station as well as operations within unpressurized Space Station modules. The system will support assembly, maintenance, repair, inspection, and servicing of Station and user systems.

The EVA system consists of the the Space Station Extravehicular Mobility Unit (EMU); EVA crew and equipment mobility aids; EVA crew rescue and equipment retrieval provisions; EMU contamination detection and decontamination unit; and EVA lighting, generic tools, and miscellaneous support equipment.

One of the space suit designs under study would contain mobility joint systems, a rapid on/off entry closure system, an extravehicular hazards protection coverlayer, and provisions for quick, on-orbit change of space suit size and hardware components.

The portable life support system contains regenerable, non-venting heat rejection and carbon dioxide absorber systems as well as an automatic temperature control system for regulation of flow conditions to the Liquid Cooling Ventilation Garment (LCVG) worn by crewmembers for removal of metabolic heat generated during EVA. The portable life support system also contains provisions for on-orbit servicing and automatic checkout.

Environmental Control and Life Support System (ECLSS)

The ECLSS provides a habitable environment for crew and biological experiment specimens. The system maintains cabin atmosphere temperature, humidity, pressure, and composition. It provides potable and hygiene water, processes and stores biological wastes, and supports crew EVAs. The ECLSS provides air cooling of equipment and detection and suppression of fires.

The U.S. ECLSS hardware is distributed throughout pressurized U.S. elements and operates continuously. Life critical hardware is located in each of the two U.S. modules to provide redundancy. Each life critical subsystem is sized to support a crew of 8 for 45 days under emergency conditions. The atmosphere control and supply hardware required for repressurization is located in each U.S. element (as is fire detection and suppression equipment). The ECLSS is composed of the following subsystems: temperature and humidity control, atmosphere control and supply, atmosphere revitalization, fire detection and suppression, water recovery and management, waste management, and EVA support.

To ensure commonality, ECLSS controllers are common with the DMS processors and are part of the DMS architecture. The controllers ensure safe, efficient operations and communicate ECLS status to crewmembers via the DMS. All instrumentation required for control and monitoring of the ECLSS and interfacing with the C&W system is part of the ECLSS architecture. See Figure A-13.

Man Systems

Man Systems is a term used to describe a distributed system for crew habitation, equipment, and other necessities for a productive and sustained working environment. Included in Man Systems are subsystems that support crew safety, health, hygiene, nutrition, Station operations, housekeeping, and stowage. Man Systems hardware and functions are allocated to all pressurized volumes and interact with many Space Station systems and subsystems. A major portion of these accommodations is in the habitation module. The Man Systems principal interface is with the Station DMS. The electronic core consists of a Multipurpose Applications Console (MAC) with displays and controls, audio and video interfaces, resident firmware, and overall software. Areas involving Man Systems and crew support shall be designed to facilitate human productivity and habitability. Crew interfaces and associated equipment will be designed for ease of maintenance, housekeeping, contamination control, and crew safety. In particular, it is vital to Man Systems to have in place standardized emergency controls and procedures. See Figure A-14.

Fluid Management System (FMS)

The FMS encompasses the distributed fluid systems of the Space Station Program. The distributed fluid systems of the FMS generally consist of two different types, supply and disposal. The first combines the requirements of several users of the same fluid into a centralized resupply, storage, and distribution system which provides the fluid to the users at a specified interface condition. The second combines common requirements of several users for vacuum and fluid disposal into an integrated system. Fluid systems include nitrogen, water, and waste fluids. See Figure A-15.

PLATFORMS

The Platforms are the orbiting, unmanned elements of the Space Station system designed to support long-term, autonomous, commercial, scientific, and technological ventures and investigations. The Program includes two polar platforms, one provided by the United States and one provided by ESA.

U.S. Polar Orbiting Platform (POP)

The U.S. polar platform will carry instruments that interface directly with the platform. Operating in a near-polar orbit, the platform will support the following types of missions: Earth biological and geological observations, oceanographic and ice activity studies,

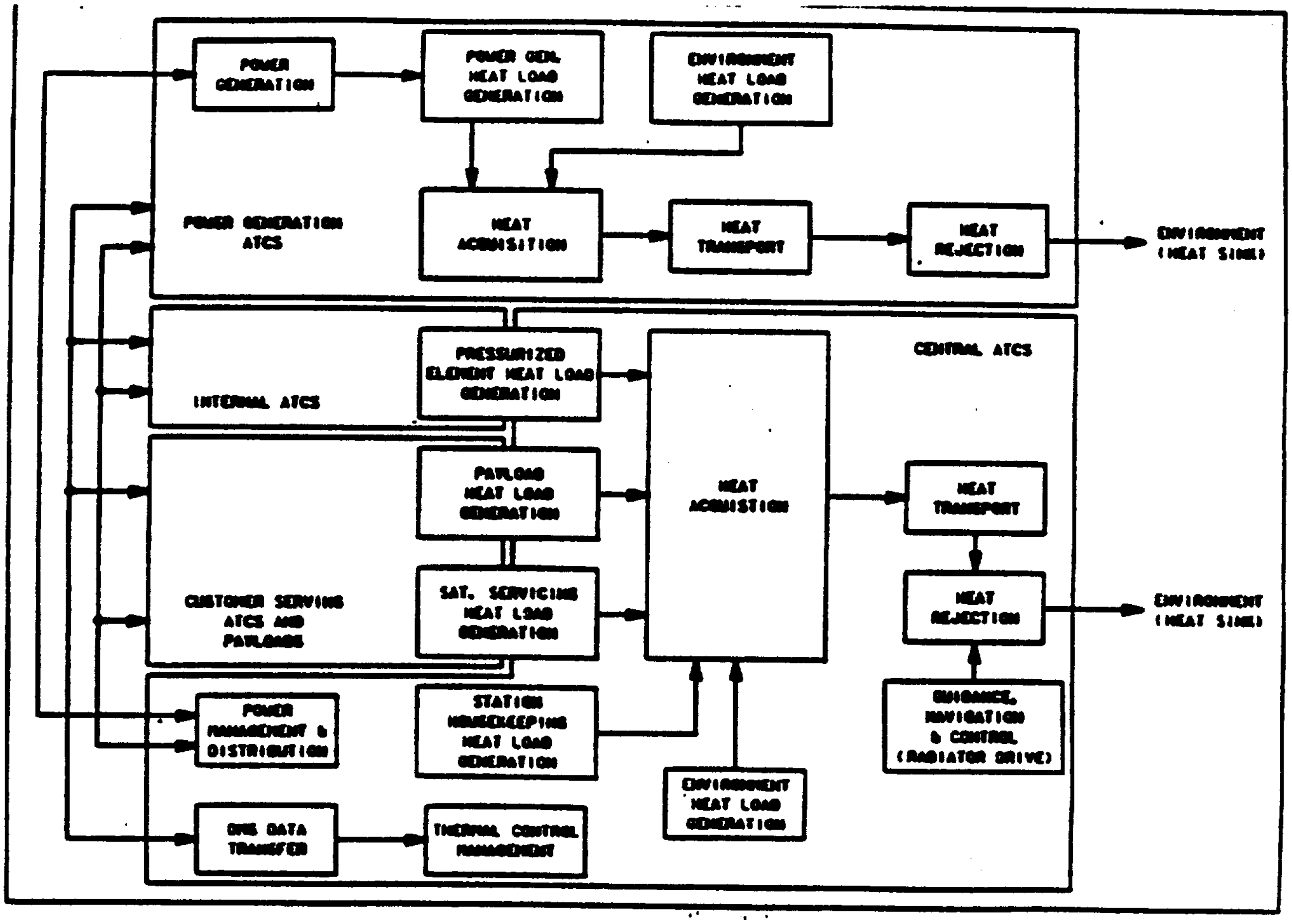

Figure A-12. Active Thermal Control System

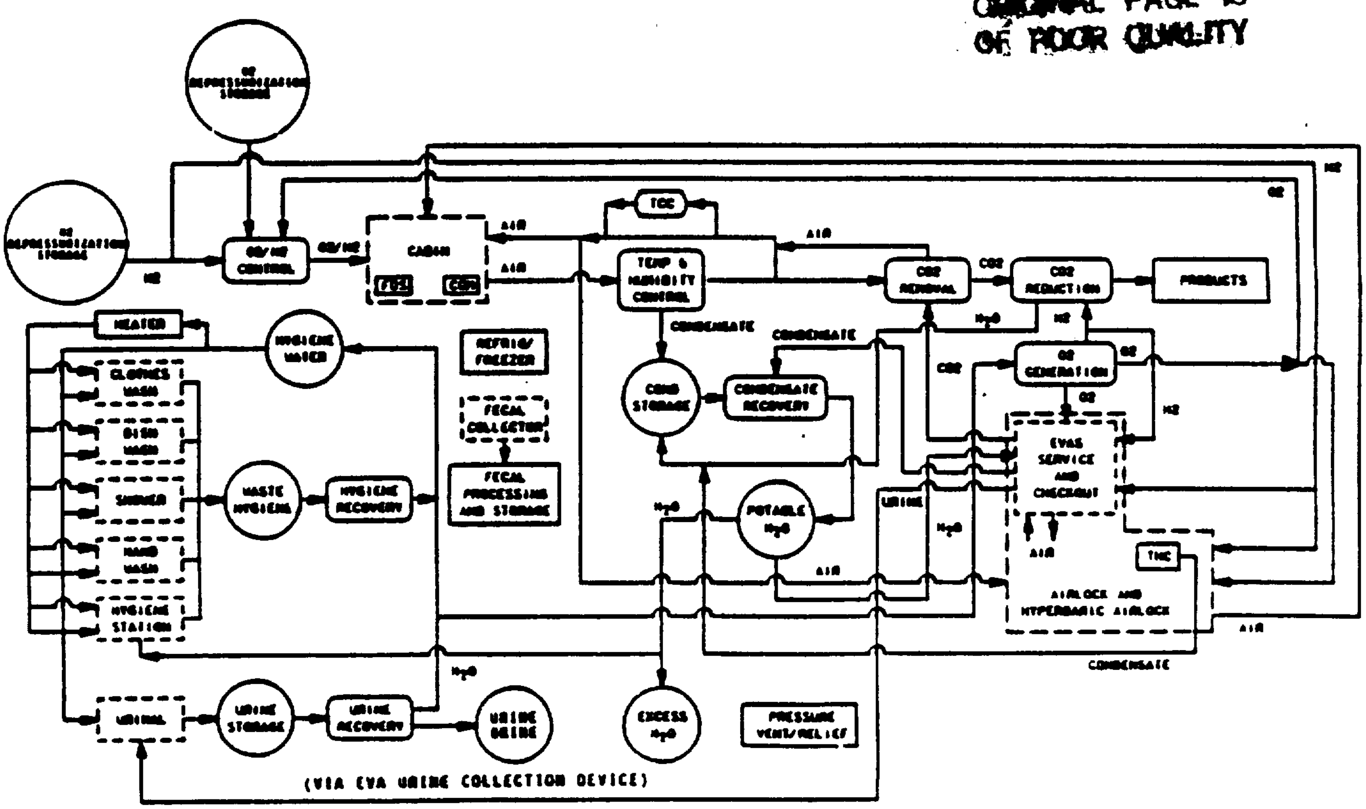

Figure A-13. Space Station ECLSS Overview

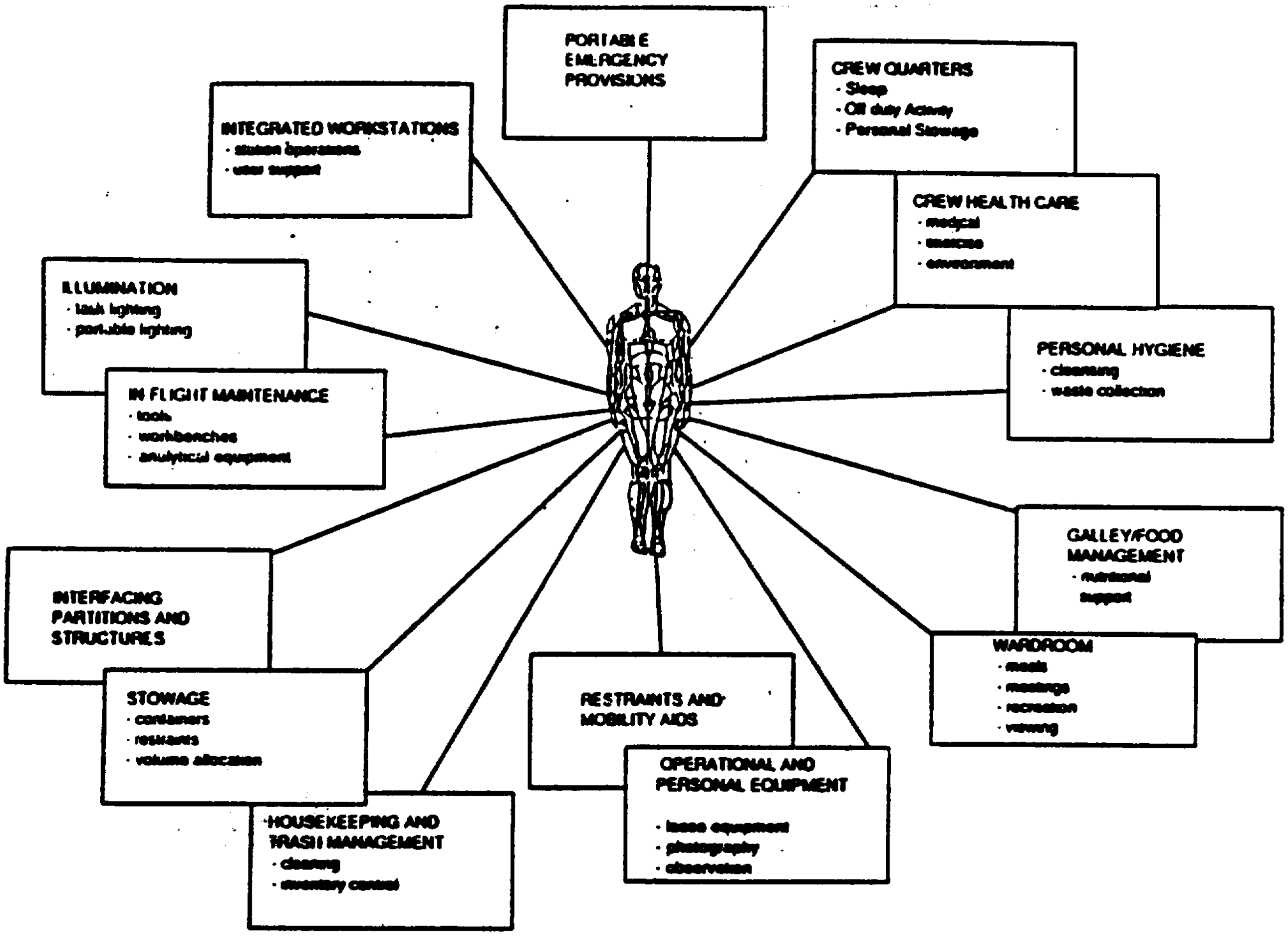

Figure A-14. Man Systems

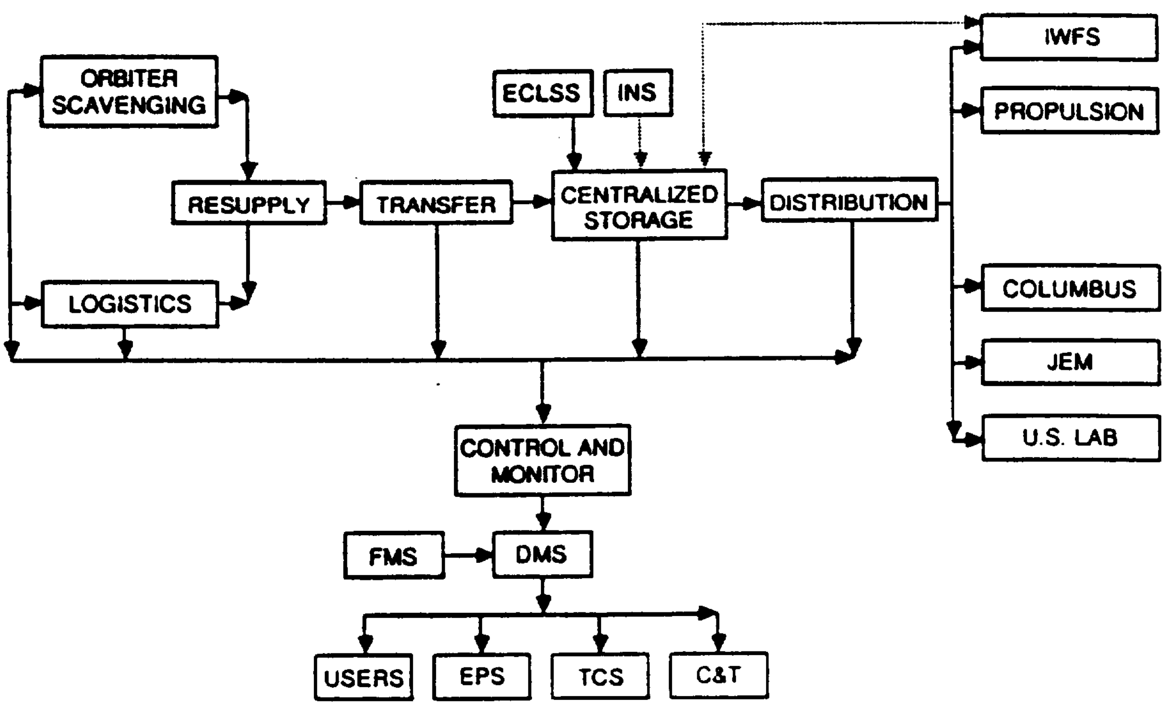

Figure A-15. Integrated Water System (IWS)

Earth lower-and upper-atmospheric monitoring and research, solar observations, and plasma physics measurements.

The platform major modules are the primary carrier, the supplemental carrier, and the propulsion module. Platform resources are supplied by modular ORUs. ORUs are both standard, those which package resources into standard-sized units and use a standard interface connector, and nonstandard, those which require unique packaging and mounting (e.g., solar arrays, antennas, magnetic torquer bars).

The primary and supplemental carriers will accommodate both resource ORUs and payloads. The primary carrier, however, may contain key resources not supported by the supplemental carriers. The primary carrier will contain all of the power generation capability (i.e., solar arrays and drives), the standard C&T resources, and the interface to the propulsion module. The supplemental carrier, in addition to the payloads it carries, will bring the additional resources such as battery and data storage ORUs needed to support an increased complement of users. Consequently, the EPS and the DMS will be distributed across the carriers to supply the entire platform resource needs. The thermal system, however, will be a hybrid system with each carrier being thermally self-sufficient so that thermal fluid transfer across carrier interfaces will not be required.

The primary and supplementary carrier assemblies use the same modular structural components. This allows variable module lengths to accommodate the requirements of a particular complement of payloads and resource ORUs. The primary and supplementary carriers will provide a grid pattern of standardized resource interface connectors for payloads. The same standard interface connectors will be used for ORUs. Resources include structural, power, thermal, and data interfaces.

Payloads can be attached to the grid locations individually, or an assemblage of smaller payloads can share a single grid interface by being integrated onto a common interface plate. See Figure A-16.

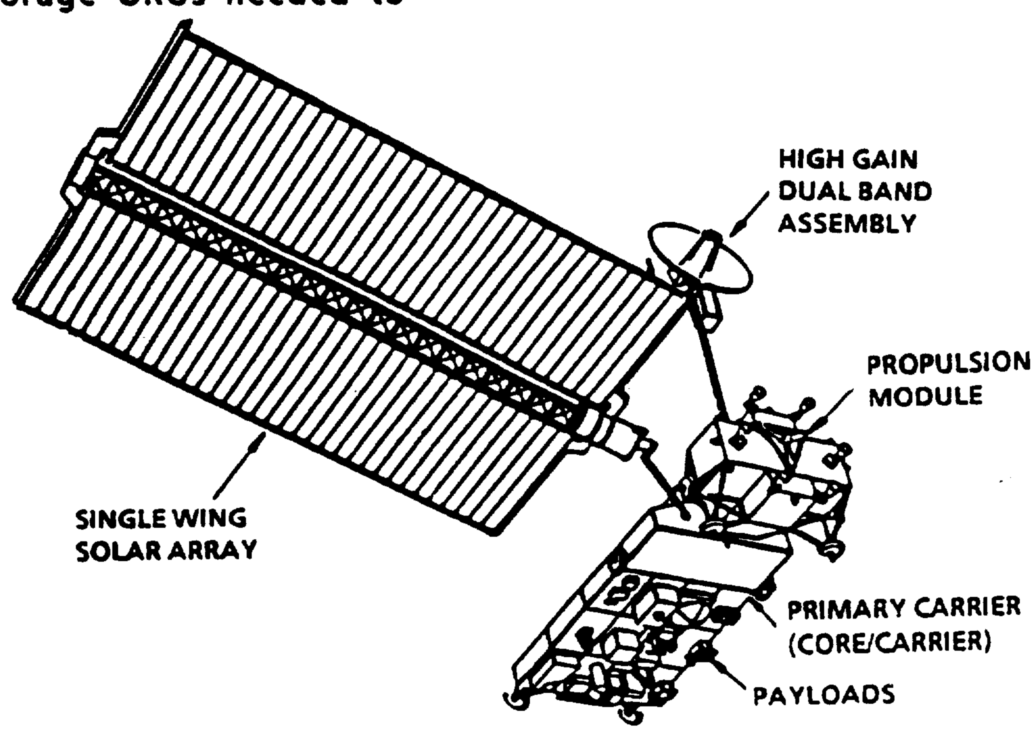

Figure A-16. United States Polar Platform

ESA Polar Platform

The ESA Polar Platform is an unmanned free-flyer providing standard resources (power, pointing, communications, etc.) primarily to Earth observation payloads requiring a low-Earth, Sun synchronous orbit. See Figure A-17.

The platform reference configuration includes a propulsion module, a utilities and payloads structure, a two-wing solar array, nickel-hydrogen batteries and radiators, and communications and tracking subsystems. Current studies include backup launch vehicle alternatives, servicing scenario options, and a review of commonality between the platform utilities module and the Man-Tended Free Flyer (MTFF) Resource Module.

ESA Man-Tended Free Flyer (MTFF)

The MTFF is an ESA-built, unmanned, pressurized laboratory for long duration microgravity applications in the fields of fluid physics, life, and material sciences. It is designed for launch by an Ariane 5 into a Space Station compatible orbit with periodic servicing at the Station. The initial Station servicing will not occur earlier than one year following the completion of on-orbit assembly.

The MTFF consists of a two-segment Pressurized Module (PM) supported by an externally attached Resource Module (RM). MTFF payloads are carried within the two cylindrical segments of the PM which are identical to those of the Columbus Attached Pressurized Module (APM). Inside the PM are single and double racks, and a workbench available for crew activities during the servicing periods when Station standard atmosphere is maintained. The RM supplies the basic power, communications and control for the configuration and houses ORUs containing the subsystems that supply the MTFF and its payloads with resources. Rollout solar arrays and a deployable antenna are attached. Attitude control is maintained through liquid propellant thrusters and cold-gas thruster systems for proximity operations. See Figure A-18.

CREW EMERGENCY RETURN VEHICLE (CERV)

Crew safety is an essential consideration in the development of Space Station. The return of the crew in the event of NSTS unavailability, a major system failure aboard the Space Station, injuries or illness may be required. Therefore, NASA has initiated a definition study for a Crew Emergency Return Vehicle (CERV).

The current concept is that the CERV would be capable of launch on the NSTS or ELV, berthing at the Space Station in a quiescent mode for extended periods, separation from the Space Station, limited orbital operations, guided entry from Earth orbit to a preselected landing site on Earth, and final landing. To have these capabilities the CERV would include the following subsystems: electrical power, environmental control life support, thermal control, communications and tracking, data management, guidance, navigation and control, attitude control, propulsion, man systems, displays and controls, and structure. Future decisions on CERV development will be made after the system definition studies which are scheduled to begin in January 1988.

INDUSTRIAL SPACE FACILITY (ISF)

NASA and Space Industries Partnership entered into a Space System Development Agreement on August 20, 1985, in support of the development by

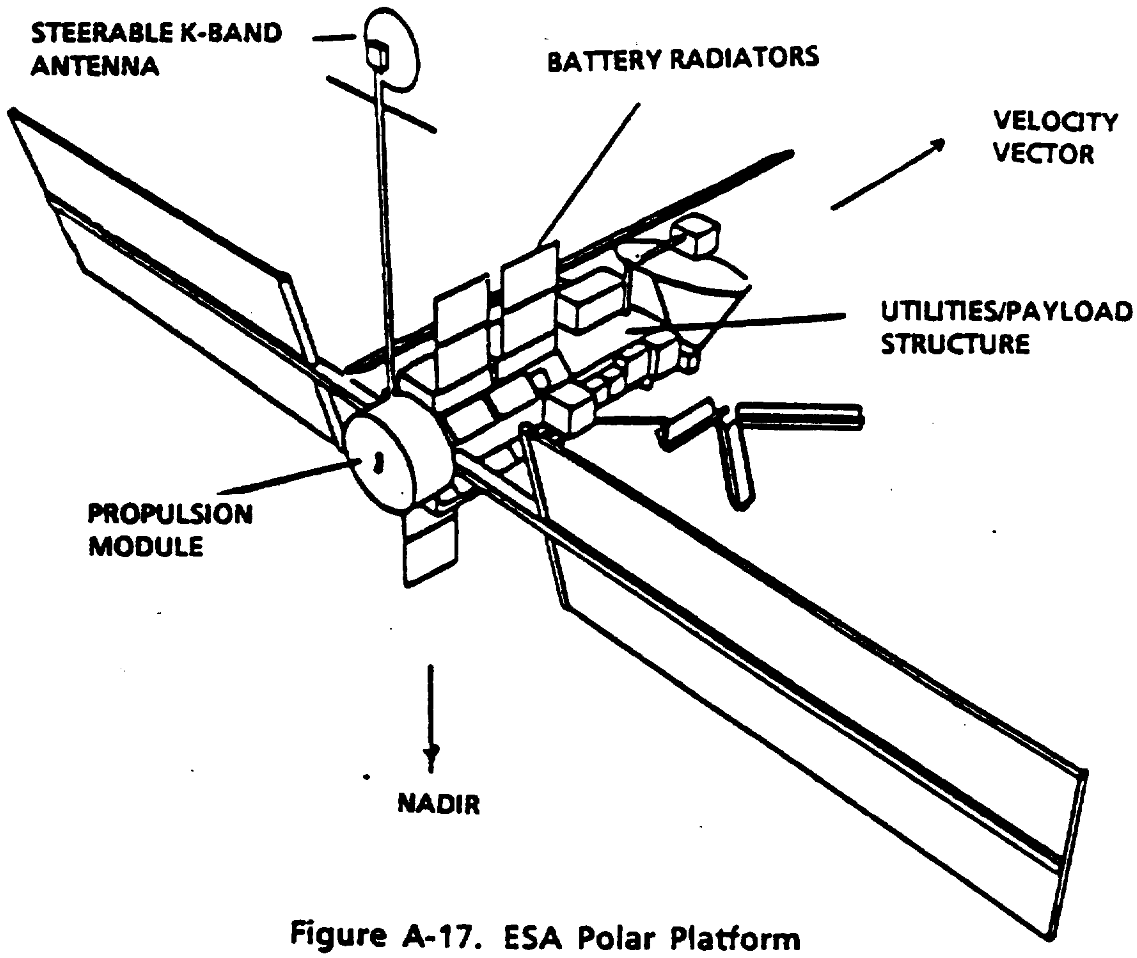

Figure A-17. ESA Polar Platform

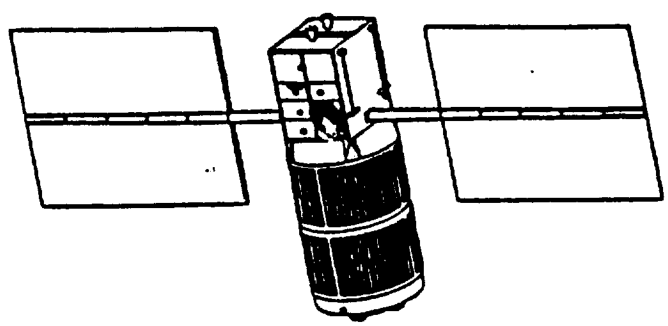

Figure A-18. ESA Man Tended Free Flyer

Space Industries of an Industrial Space Facility (ISF) – a man-tended, NSTS-deployed and NSTS-serviced free-flyer. Space Industries plans to deploy and operate the ISF several years prior to the Space Station initial operation.

The Space Station and ISF programs can be considered to be complementary and in some respects elements may be similar. There are aspects of the two programs that will be of mutual interest and of potential benefit to both NASA and Space Industries. The ISF will be developed commercially and independently of the Space Station Program.

The ISF is foreseen to operate for extended periods in orbit in an automated mode with brief interim periods docked to the Orbiter at which time it may be manned for servicing and research. During these manned periods, the crew may perform such functions as research, repairs, servicing, equipment change-out, harvesting of products, and cleaning and restocking or research and production apparatus.

The ISF Program will undertake a number of activities which are common to the Space Station Program. Therefore, cooperation and data exchange between the two programs could be mutually beneficial.

ASSEMBLY SEQUENCE

The following assembly sequence is the reference upon which NASA, U.S. industry, and the potential international partners will base their detailed Space Station design and development. This sequence may change, but at this time, it is the baseline sequence for the Space Station Program.

The assembly sequence consists of 20 NSTS launches including 13 for the manned base assembly, four for logistics, two for outfitting and user payloads, and one for the deployment of the U.S. polar platform. Additionally, two Ariane launches are planned for the deployment of the ESA polar platform and the ESA Man-Tended Free Flyer. See Table A-1.

The U.S. laboratory module will be launched on assembly flight MB-6. It will be partially outfitted, containing approximately 25 percent of the 44 equipment racks it will ultimately hold. The module will include basic support systems such as power, air conditioning, and water. A man-tended capability will be achieved with this flight. Flight OF-1 will be for outfitting the U.S. laboratory.

Permanently manned capability with a crew of four will be achieved with assembly flight MB-9. The flight will deliver logistics modules and equipment capable to sustain the crew.

Table A-1. Reference Assembly Sequence

FLIGHT		DESCRIPTION/MANIFEST	
1.	(MB-1)	18.75 PV POWER, TRUSS, FTS, ERECTOR SET, AVIONICS, RCS	
2.	(MB-2)	18.75 PV POWER, TRUSS, RCS, ATT. PAYLOADS	
3.	(MB-3)	AFT NODES, RCS	
4.	(MB-4)	TCS, MSC, PAYLOADS, RCS, SSEMU	
5.	(MB-5)	AIRLOCKS (2), SSRMS, PAYLOADS, POINTING SYSTEM	
6.	(P-1)	U.S. POLAR PLATFORM (WTR)	
7.	(MB-6)	U.S. LAB MODULE	MTC
8.	(OF-1)	LAB MODULE OUTFITTING	
9.	(MB-7)	U.S. HAB MODULE	
	(A-1)	ESA POLAR PLATFORM, ARIANE-5	
10.	(MB-8)	FORWARD NODES, CUPOLA, OUTFITTING	
11.	(MB-9)	CREW (4), LOGISTICS, OUTFITTING	PMC
12.	(MB-10)	18.75 PV POWER (2), TRUSS	
13.	(L-1)	LOGISTICS, OUTFITTING, P/L, CREW	
14.	(MB-11)	JEM, EF #1, CREW (8)	
15.	(L-2)	LOGISTICS, CREW	
16.	(MB-12)	ESA MODULE	
17.	(L-3)	LOGISTICS, OUTFITTING, CREW	
18.	(MB-13)	ELM, EF #2, P/L, OUTFITTING	
19.	(L-4)	LOGISTICS, OUTFITTING, P/L, CREW	
20.	(OF-2)	OUTFITTING, SPDM	
	(A-2)	ESA MTFF (ARIANE)	

KEY

A = Ariane
HAB = Habitation
L = Logistics
LAB = Laboratory
MB = Man Based
OF = Outfitting
P = Platform

APPENDIX B
REFERENCE DOCUMENTS

Document Number	Reference Documents
TBD	Program Requirements Document, August 15,1987.
JSC 30000	Program Definition and Requirements Document.
JSC 30456	Space Station System Engineering Process Requirements. December 30, 1986.
JSC 30255	Baseline Configuration Document. February 15, 1987.
JSC 30257	Architectural Control Document: Man Systems. January 15, 1987.
JSC 30262	Architectural Control Document: Environmental Control and Life Support System. Undated.
JSC 30263	Architectural Control Document: Electrical Power January 15, 1987.
JSC 30264	Architectural Control Document: Fluid Management Systems. January 15, 1987.
	Management Publications
NHB 1700.1	NASA Safety Manual
NHB 5300.4 (1A)	Reliability provisions for Aeronautical Space and System Contractors.
NHB 1700.7A	Safety Policy and Requirements for Payloads Using the STS.
KHB 1700.7A	STS Payload and Ground Safety Handbook.

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APPENDIX C
ACRONYM LIST

A&R
Automation and Robotics
ACD
Architectural Control Document
APAE
Attached Payloac Accommodation Equipment
APM
Astronaut Positioning Mechanism
ATCS
Active Thermal Control System

C&T
Communication and Tracking
CAD
Computer Aided Design
CAE
Computer Aided Engineering
CCB
Configuration Control Board
CCZ
Command and Control Zone
CDR
Critical Design Review
CEI
Contract End Item
CERV
Crew Emergency Return Vehicle
CSD
Contract Start Date
CUP
Consolidated Utilization Plan
CY
Calendar Year

DCR
Design Certification Review
DDT&E
Design, Development, Testing and Evaluation
DMS
Data Management System

ECLS
Environmental Control Life Support
ECLSS
Environmental Control Life Support System
EEE
Electrical, Electronic and Electromechanical
ELM
Experiment Logistics Module

ELV
Expendable Launch Vehicle
EMU
Extravehicular Mobility Unit
EPS
Electrical Power System
ESA
European Space Agency
ESC
Engineering Support Center
EVA
Extravehicular Activity

FEL
First Element Launch
FMEA
Failure Modes and Effects Analysis
FMS
Fluid Management System
FRR
Flight Readiness Review
FSE
Flight Support Equipment
FTS
Flight Telerobotic Servicer
FY
Fiscal Year

GN&C
Guidance, Navigation, and Control
GPS
Global Positioning System
GSE
Ground Support Equipment
GSFC
Goddard Space Flight Center

JEM
Japanese Experiment Module
JPL
Jet Propulsion Laboratory
JSC
Johnson Space Center

KSC
Kennedy Space Center
kW
Kilowatt

LCVG
Liquid Cooling Ventilation Garment
LeRC
Lewis Research Center

MOU
Memorandum of Understanding
MPAC
Multipurpose Application Console
Mpbs
Megabits per second
MRDB
Mission Requirements Data Base
MRS
Mobile Remote Servicer
MSC
Mobile Servicing Centre
MSFC
Marshall Space Flight Center
MSIF
Multi-System Integration Facility
MSS
Mobile Servicing System
MTC
Man Tended Capability
MTFF
Man Tended Free Flyer

NASA
National Aeronautics and Space Administration
NRC
National Research Council
NSC
National Security Council
NSTS
National Space Transportation System

OAST
Office of Aeronautics and Space Technology
OCP
Office of Commercial Programs
OMB
Office of Management and Budget
OMS
Operations Management System
OMV
Orbital Maneuvering Vehicle
ORR
Operations Readiness Review
ORU
Orbital Replacement Unit
OSE
Orbital Support Equipment
OSF
Office of Space Flight

OSO
Office of Space Operations
OSSA
Office of Space Science and Applications
OSTP
Office of Science and Technology Policy

PAM
Payload Accommodations Manager
PCC
Program Coordination Committees
PDR
Preliminary Design Review
PLC
Pressurized Logistics Carrier
PMC
Permanently Manned Capability
PMS
Performance Measurement System
POIC
Payload Operations Integration Center
PORR
Preflight Operations Readiness Review
PRR
Program Requirements Review
PSC
Program Support Contractor
psi
pounds per square inch

RMS
Remote Manipulator System
RFP
Request for Proposal

SE&I
System Engineering and Integration
SPDM
Special Purpose Dextrous Manipulator
SRM&QA
Safety, Reliability, Maintainability, and Quality Assurance
SSCB
Space Station Control Board
SSCC
Space Station Control Center
SSE
Software Support Environment
SSIS
Space Station Information System
SSPF
Space Station Processing Facility
SSPO
Space Station Program Office

SSPSC
Space Station Platform Support Center
SSSC
Space Station Support Center
SSTF
Space Station Training Facility
SSUB
Space Station Users Board

TCS
Thermal Control System
TDRS
Tracking and Data Relay Satellite
TDRSS
Tracking and Data Relay Satellite System
TMIS
Technical and Management Information System
TOP
Tactical Operations Plan

ULC
Unpressurized Logistics Carrier
UOB
Utilization and Operations Board

WBS
Work Breakdown Structure